FIVE JAPANESE PAPERS ON SKIPJACK

SPECIAL SCIENTIFIC REPORT: FISHERIES No. 83

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

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Explanatory Note

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Washington, D.C.
August, 1952

United States Department of the Interior
Oscar L. Chapman, Secretary
Fish and Wildlife Service
Albert M. Day, Director

Special Scientific Report Fisheries
No. 83

FIVE JAPANESE PAPERS ON SKIPJACK

Translated from the Japanese language by

W. G. Van Campen

Pacific Oceanic Fishery Investigations

CONTENTS

Page

1. Skipjack fishing grounds and oceanographic conditions in the Northeastern sea area, by Takeo Sasaki 1

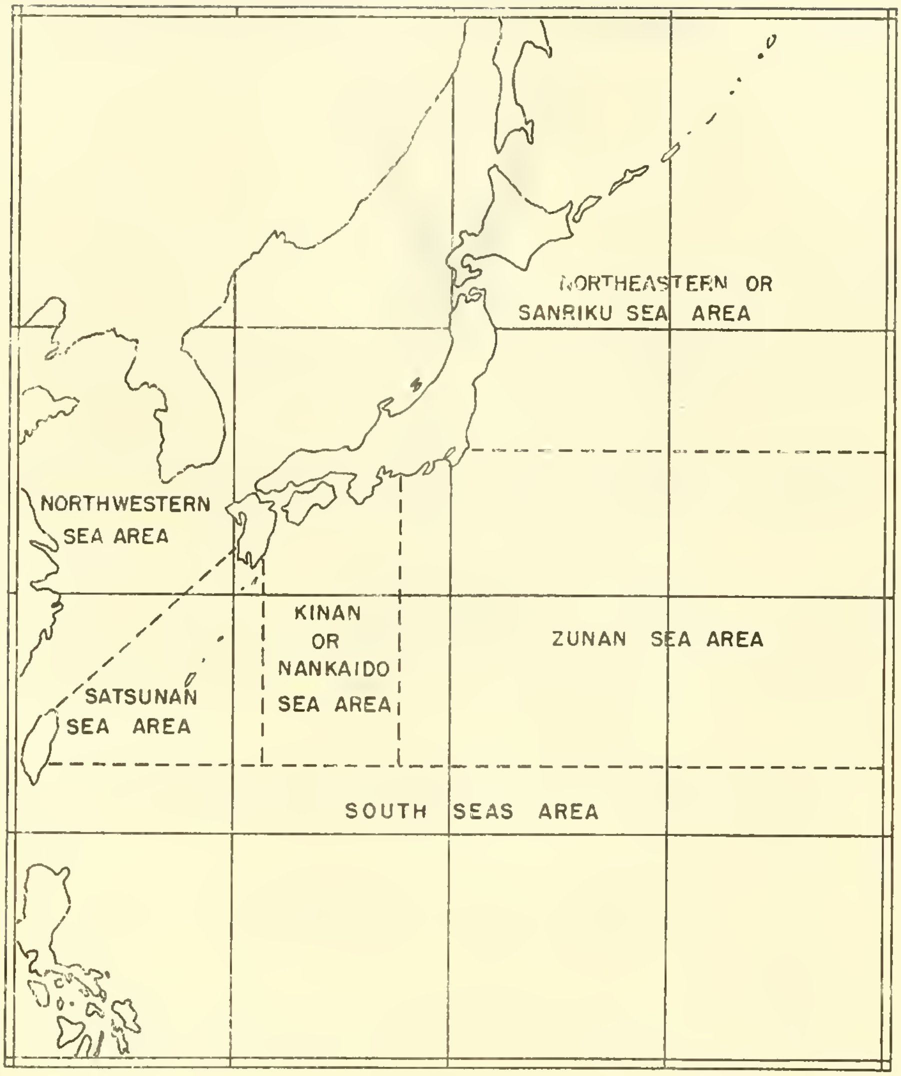
2. On the stock of skipjack, by Morisaburō Tauchi.................. 22

3. Notes on the shoal of bonito /skipjack, Katsuwonus pelamis/ along the Pacific coast of Japan, by Hiroaki Aikawa.............. 32

4. Local variations in the composition of skipjack (Katsuwonus pelamis) schools, by Michitaka Uda and Jirō Tsukushi............ 51

5. Types of skipjack schools and their fishing qualities, by Michitaka Uda.. 68

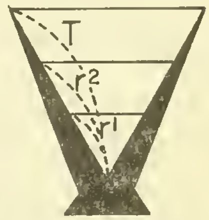
WASHINGTON: AUGUST 1952



Translator's note: This sketch map has been added ~~to~~ to this set of translations in order to enable the reader to identify the areas discussed in the papers.

ERRATA AND ADDENDA

Page	Line	
31	5	For "shipjack" read "skipjack"
33	Fig. 1B	The insert should be labeled as follows:



37	2	For "vetebral" read "vertebral"
55	3	For "north and west" read "southwest"
75	28	The symbol for number of poles is a lower-case L, not the figure one.
75	30	For "$\frac{N}{t}$" read "$\frac{N}{lt}$"
73	35	For "Here is a constant." read "a here is a constant."

Miyagi Prefecture Fisheries Experiment Station, Fisheries Guidance Materials No. 1. March 1939.

Skipjack Fishing Grounds and Oceanographic Conditions in the Northeastern Sea Area

by

Takeo Sasaki

Contents

Preface — Page

(1) Surface water temperatures and the distribution of skipjack fishing grounds in the Northeastern Sea Area.......... 2

(2) Lines of discontinuity and distribution of skipjack fishing grounds within the area of favorable water temperatures in the Northeastern Sea Area.......... 6

(3) Types and density of skipjack schools and their biting qualities in the Northeastern Sea Area...... 9

(4) Sources of the skipjack schools of the Northeastern Sea Area.......... 11

(5) Autumn low pressure areas and sea conditions and the skipjack fishing grounds on the Northeastern Sea Area.......... 13

(6) Data for the prediction of the abundance or scarcity of skipjack in the Northeastern Sea Area.. 13

(7) Skipjack landings at five fishing ports in Miyagi Prefecture.......... 17

(8) On the migrations of the skipjack schools.......... 18

Appendix

On the skipjack taken in the winter tuna longline fishery 20

Preface

In the past this Station has published reports of, among other things, the progress of its work on the relationship between sea conditions and skipjack fishing grounds in the Northeastern Sea Area. The plan in the present case is to select from these reports only the material of a basic character and, adding to it data abstracted from the reports of the National Fisheries Experiment Station, to present it as a summary for the use of the fishermen of this prefecture. It is hoped that this paper may be of some use to persons actually engaged in the skipjack fishery.

This opportunity is also taken to express the hope that all persons in the industry will ungrudgingly proffer the data which they have obtained, not only in this fishery alone but in all departments of the industry, in order to assist the Station in projects of this sort and to work for the improvement and development of Miyagi fisheries.

(1) Surface water temperatures and the distribution of skipjack-fishing grounds in the Northeastern Sea Area

According to studies made in the Northeastern Sea Area since 1929--

a. Suitable temperatures are $20^\circ - 24^\circ$ C. Within this range, the greatest number of schools appeared at $22^\circ - 23^\circ$.

b. As the areas of suitable water temperatures shift, the skipjack fishing grounds within them shift. (See the chart of the movements of the center of gravity of the fishing grounds).

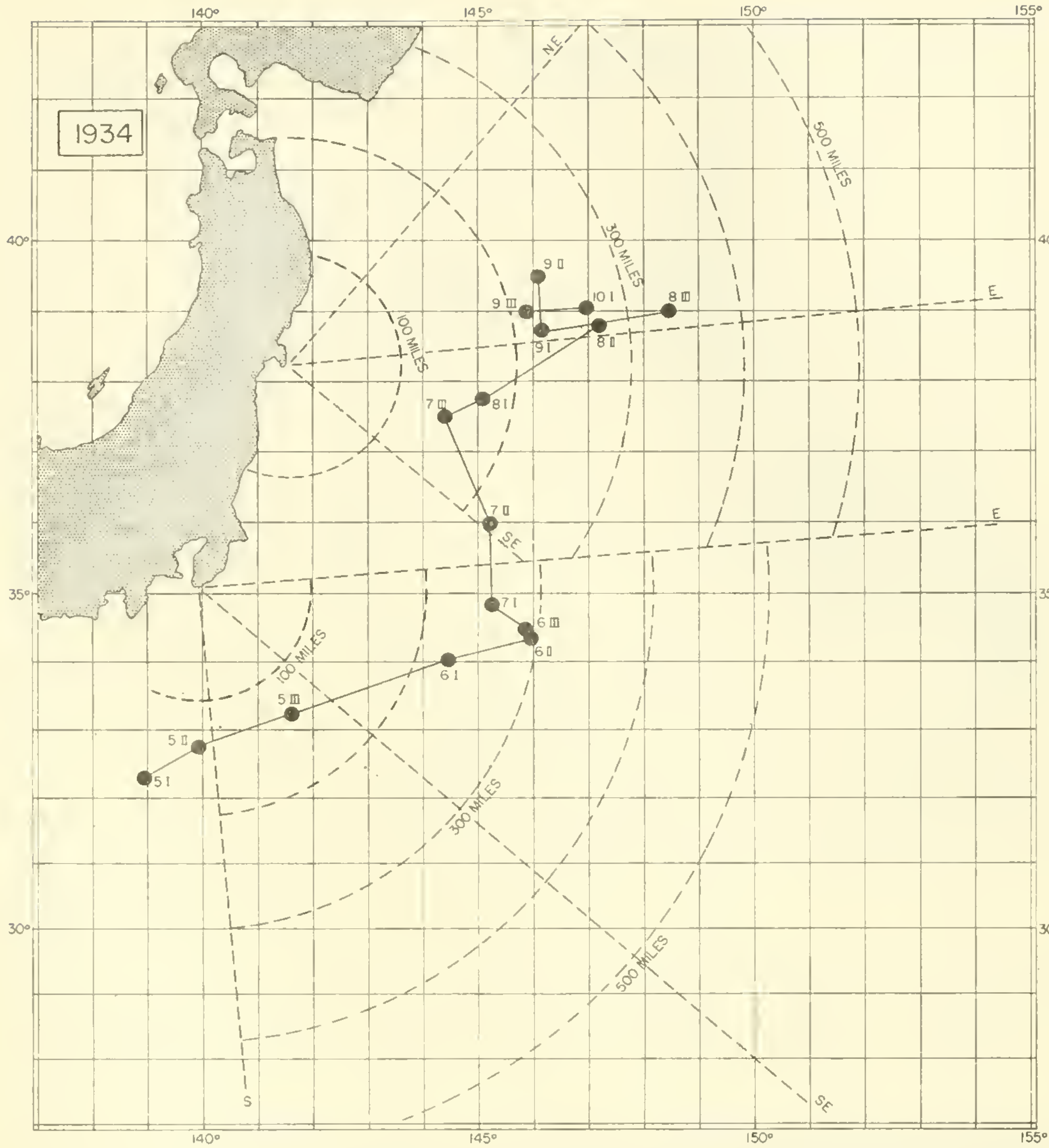


CHART OF SHIFTS IN THE CENTER OF THE SKIPJACK GROUNDS
ARABIC NUMERALS INDICATE MONTHS
I, II, III INDICATE FIRST, SECOND, AND THIRD 10 DAYS OF EACH MONTH.

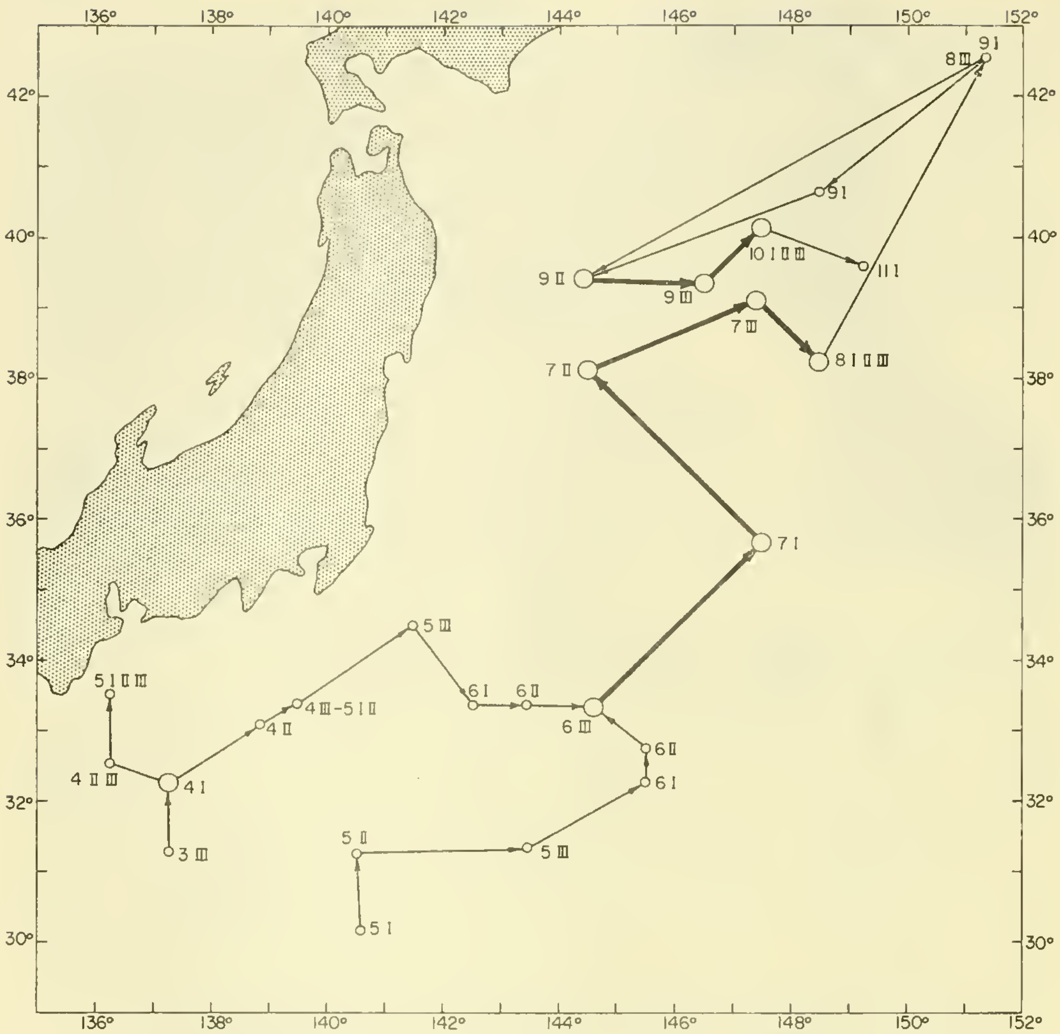


CHART OF SHIFTS OF THE CENTER OF THE SKIPJACK GROUNDS IN 1937
ARABIC NUMERALS REPRESENT MONTHS
I, II, AND III REPRESENT THE FIRST, SECOND, AND THIRD 10 DAYS OF EACH MONTH.

These facts which have come to be known can be shown in more detail as follows:

Surface Water Temperatures on Skipjack Grounds

	June			July		
	1-9	10-19	20-30	1-9	10-19	20-30
Temperature range within which fish were caught	18°-23°	19°-24°	19°-25°	19°-26°	20°-26°	20°-26°
Range of suitable temperatures	20°-22°	20°-22°	21°-23°	22°-23°	22°-23°	22°-23°
Most favorable water temperature	21°	21°	22°	22°	22°	22°

	August			September		
	1-9	10-19	20-30	1-9	10-19	20-30
Temperature range within which fish were caught	20°-26°	20°-26°	19°-26°	18°-26°	18°-25°	18°-24°
Range of suitable temperatures	22°-23°	22°-24°	22°-24°	22°-23°	22°-23°	21°-22°
Most favorable water temperature	22°	23°	23°	22°	22°	22°

	October		
	1-9	10-19	20-30
Temperature range within which fish were caught	18°-23°	18°-21°	18°-21°
Range of suitable temperatures	20°-21°	18°-21°	18°-21°
Most favorable water temperature	21°	20°	20°

As the foregoing table shows:

a. The range of water temperatures within which fish were taken was 18° - 26°.

b. The most favorable water temperature changes with the season (during the fishing season of June - November) from a lower to a higher and then back again to a lower temperature.

Therefore in the choice of fishing grounds it is essential to take the 20° isotherm as the center off the Bōsō Peninsula (Chiba Prefecture) up to May - June, and the 22° isotherm off Tokiwa and Sanriku (northeastern Japan) from July to September, or in other words to seek the most favorable temperature for the season, as given in the preceding table. This should be clearly apparent from the fact that over 40 percent of the total catch was taken from fishing grounds with these temperatures. (In the middle of summer there are also sometimes fishing grounds on which 24° is the most favorable temperature. These will be discussed later.) Of course, in making this choice it should be within a warm-current area where the water color is 2 - 3, the transparency about 20 meters, and the specific gravity about 1.025. Particular attention should always be paid to the pattern of the northward movement of the 20° isotherm.

x x x x x x

(2) Lines of discontinuity and the distribution of skipjack fishing grounds within the areas of favorable water temperatures in the Northeastern Sea Area

Even in such areas of favorable water temperatures, the actual distribution of the skipjack fishing grounds is by no means uniform, and there is a tendency for them to be concentrated unevenly here and there. Furthermore, there are great differences in the density of the schools even though the water temperatures may be the same. What sort of oceanographic factors may give rise to this phenomenon? It is believed that in this connection the following factors cannot be overlooked:

a. As stated earlier, the main fishing grounds are always distributed within the area of favorable water temperatures having surface water of 20° - 24°, with their center at the 22° isotherm, but in view of the fact that the schools of fish assemble where there are many irregularities in the isotherms and where the isotherms

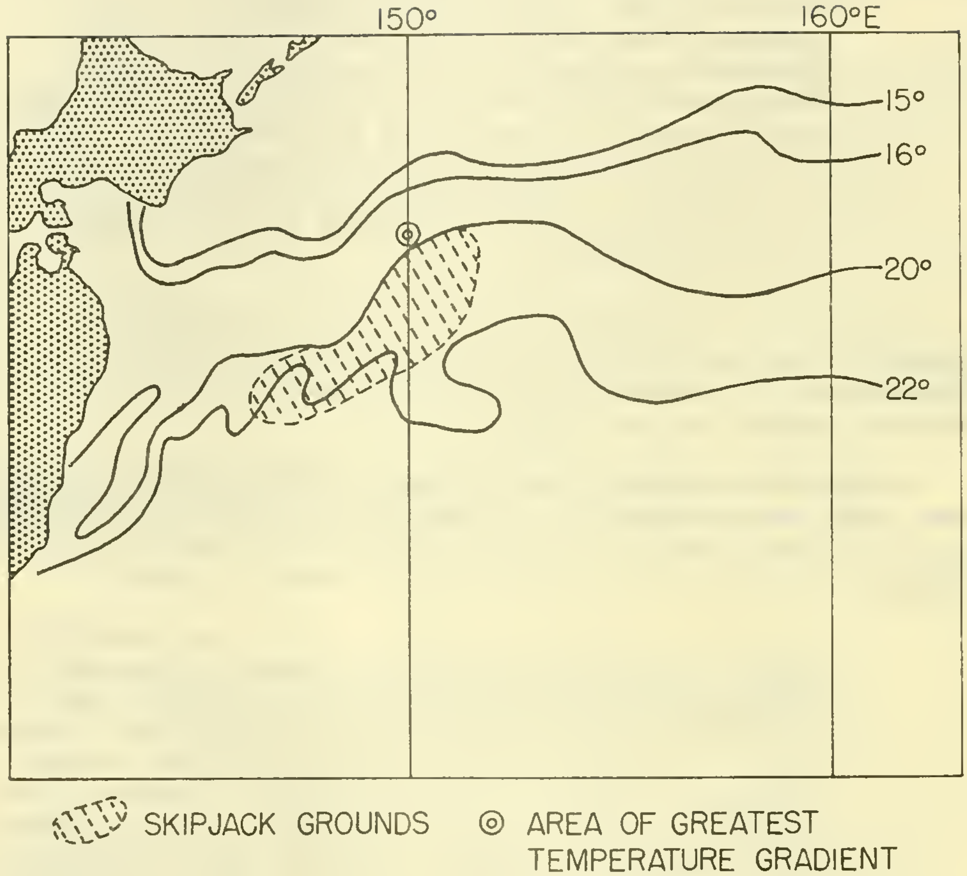
are close together, or in other words at marked current boundaries (lines of discontinuity), it may be thought that these current boundaries are the greatest factor in causing the unequal concentration of the schools. Especially in the case of the main fishing grounds of midsummer, there is a tendency for them to be located in the area of the most conspicuous boundaries between the cold current system and the northern-most extension of the 22° isotherm (where the cold and warm current systems approach each other and the gradient of the water temperature is the steepest), within which area they tend to appear at the tips of the warm water masses or on their west sides (the east sides of the cold water masses). (See the map of the distribution of the main skipjack fishing grounds and the surface water temperatures.)

Note: This corresponds with the rule concerning the fishing situation insisted upon by the late Mr. Kitahara, "The schools of fish are numerous along the line where two currents impinge on each other."

Sometimes in August a second major fishing ground, distinct from those described above, is found in an area of high temperatures and conspicuous current boundaries centering on the 24° surface isotherm, and in such years the catch is heavy.

b. Next we can cite the factor of a rich and plentiful supply of plankton along these current boundaries accompanied by a concentration of skipjack in search of food. However, it is believed that the main factor causing the concentration of schools at the current boundaries must be chance gatherings of schools which cannot escape from the areas in which they find themselves because of vortical movements where warm water penetrates the cold water. Thus it can be inferred that the more marked the impact of the currents along the boundary, the denser will be the concentration of the schools. (See the cross section of water temperatures off Kinkazan and the chart of the positions of the skipjack fishing grounds.)

Note: (a) The "current boundaries" mentioned here are the boundaries where different water systems (such as the waters of the two great systems of the Kuroshio and the Oyashio) meet and mingle (zones of convergence).



MAIN SKIPJACK GROUNDS AND SURFACE WATER TEMPERATURE, AUGUST 1935

(b) The most clearly marked current boundaries can be seen in the areas where the zone of 20° - 21° water representing the front of the warm current and the zone of 15° - 16° water representing the front of the cold current approach each other most closely.

(c) The fishermen already know from experience that the best fishing grounds are found along these current boundaries where the water temperature, salinity, water color, and transparency differ.

x x x x x

(3) Types and density of skipjack schools and their biting qualities in the Northeastern Sea Area

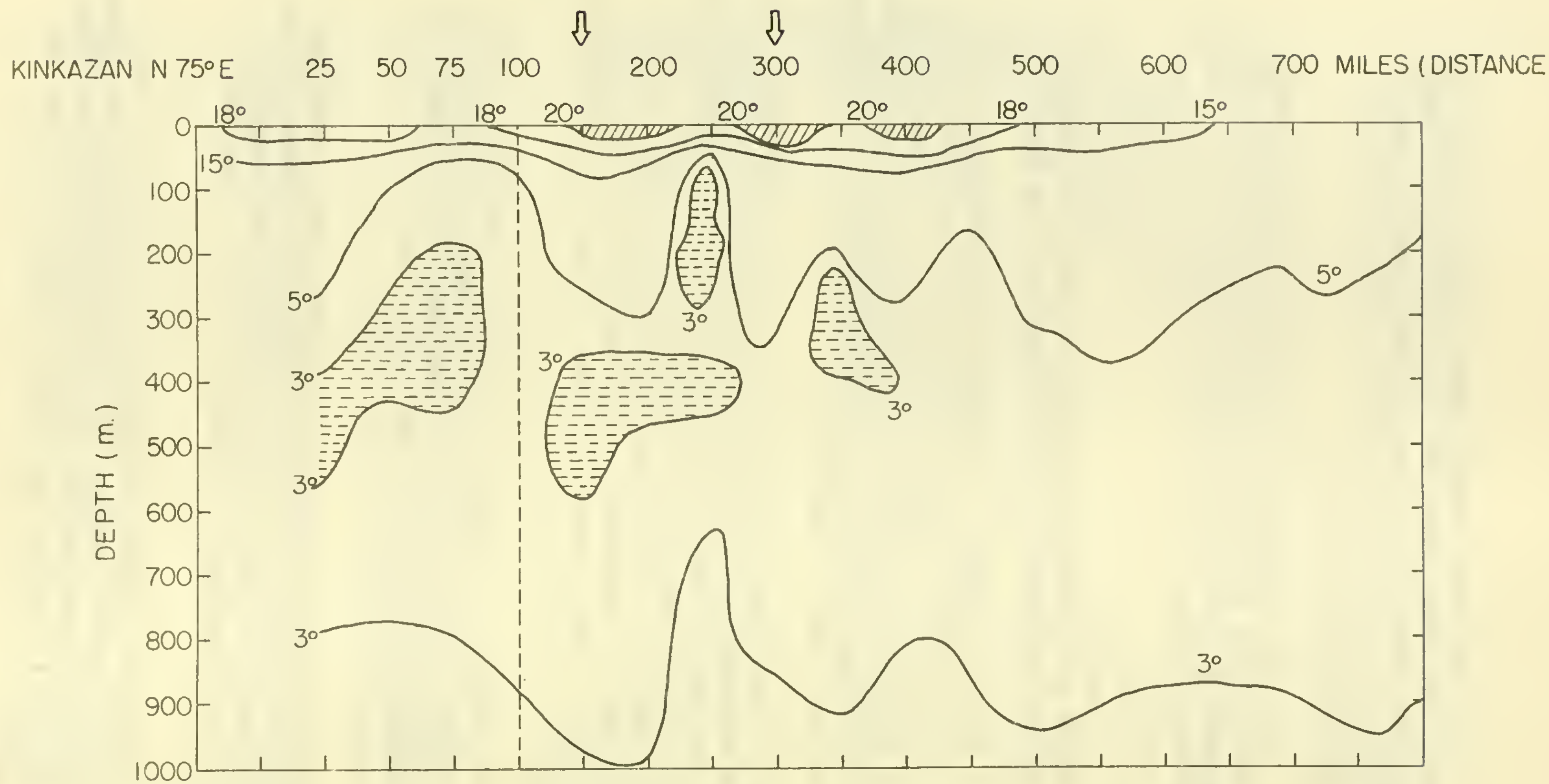
a. In this area schools accompanying sharks and unassociated schools occupy the most important place, both in terms of the number of occurrences of schools and in the total number of fish taken. Schools associated with birds, with whales, and with floating logs follow in that order of importance.

Note: In the Zunan Sea Area schools associated with birds and schools sedentary along shore or on shoals are the most important, followed by unassociated schools. The remainder are a few schools associated with driftwood and with sharks. In the Satsunan Sea Area schools associated with birds are most numerous followed by sedentary schools and schools associated with driftwood. A small number of other schools are associated with sharks.

b. The catch from individual schools is greatest in the case of schools associated with sharks, followed by those associated with driftwood and with whales. The remainder are unassociated schools and schools associated with birds, in that order.

Note.--In the Zunan Sea Area bird-associated, sedentary, and unassociated schools supply the bulk of the catch. In the Satsunan Sea Area, likewise, bird-associated and sedentary schools are most important followed by schools accompanying driftwood.

c. Except for schools associated with birds, with all other types of schools there are generally more appearances of dense schools than of sparse ones, and their density is higher than that of schools in other sea areas.



VERTICAL SECTION OF WATER TEMPERATURES AND THE POSITIONS OF SKIPJACK GROUNDS OFF KINKAZAN IN EARLY AUGUST 1934.
(⇩ INDICATES THE CENTER OF A FISHING GROUND.)

Note: In both the Zunan and Satsunan sea areas the number of occurrences of sparse schools exceeds that of dense schools.

Note: (a) This sort of distribution results from the fact that the distribution of the objects with which the schools are associated varies depending on the area and oceanographic conditions. It must be that as the skipjack schools move into various sea areas they associate themselves successively with different objects.

(b) It is thought that the particular abundance of dense schools in the Northeastern Sea Area is due to the presence of current boundaries where the water of the cold current system tries to block the extension of the waters of the warm current system.

(c) However, the greater number of dense schools and the greater number of fish taken in this sea area in mid-summer in comparison with other sea areas is general throughout the area.

d. The next characteristic of this sea area to be taken up is the fact that the skipjack schools bite far better than they do in the Zunan and Ogasawara sea areas. It is a generally known fact that the schools bite poorly in sea areas where there is too much natural food. Where plankton consisting of diatoms and noctiluca is too abundant, the schools bite poorly, but in areas where the diatoms are comparatively scarce and the plankton consists chiefly of flagellates and radiolarians the fish sometimes bite well.

x x x x x

(4) Sources of the skipjack schools of the Northeastern Sea Area

a. Among the schools from which skipjack are taken by the hook and line fishery in the Northeastern Sea Area fish of 45 - 55 cm body length are extremely numerous and as far as age is concerned fish in their fourth year are abundant. There are two different groups, migratory schools of fat fish (condition factor over 20) and sedentary schools of lean fish (condition factor under 20).

Notes: (a) The term "sedentary schools" (island-bound skipjack) is applied to those fish whose way of life is closely bound to small islands and shoals. The sedentary schools are caught in the greatest numbers as they move along the Ogasawara

and Izu chains on the way to the Northeastern Sea Area, where they are also fished.

(b) The migratory schools are fished not only in the Ogasawara and Izu areas but also in the seas to the southwest of those islands. Their distribution is broad and unselective.

b. There are thus two groups of schools of different origins coming into the Northeast Sea Area, and consequently it would appear that variations in the catch in this area are closely linked with the numbers of fish of these groups which migrate into the area. And, considering the points (1) that the migratory schools provide 80 percent of the total skipjack catch of the Northeastern Sea Area and (2) that medium sized skipjack (4 to 8 pounds) make up 70 to 80 percent of both the total number of fish taken and the number of appearances of schools, it is thought that most of the skipjack schools in the area are medium-sized migratory schools and that the numbers in which they migrate into the area have a great effect on the catch.

Notes: (a) Fish under 26 cm body length are first-year fish. Those 26 - 34 cm are second-year fish. Those 34 - 43 are third-year fish. Those 43 - 54 are fourth year fish. Fish longer than 54 cm are in their fifth year or older.

(b) Considering the catch in the Northeastern Sea Area from the point of view of the sizes of fish taken, the order of importance is medium, large, and small, but in the Zunan and Satsunan Sea Areas the order is small, medium, and large. In general, small skipjack are few in the north and numerous in the south.

(c) In the Northeastern Sea Area the catch for 1936 was the greatest in the last ten years in number of fish taken, but the fishing situation was abnormal with the main part of the catch consisting of small fish of around 2.5 pounds (under 4 pounds).

(d) Condition factor $= \dfrac{\text{weight (gr)} \times 1000}{\text{length (cm)}^3}$

x x x x x

(5) Autumn low pressure areas and sea conditions and the skipjack fishing grounds of the Northeastern Sea Area

When the autumn winds begin to blow and the season of the "descending" skipjack starts, the speed with which the center of gravity of the fishing grounds shifts to the southward is rapid directly after the passage of a low, but otherwise it shifts slowly. Every time an autumn low passes over this sea area the upper and lower layers of water are either mixed together by the stirring action of the wind, or countercurrents are caused by air cooling, or cold water from the lower levels is brought up by gyrals -- at any rate, this mixing action results in a sudden decrease in the temperature differential of the upper and lower layers. In this way the water temperature of the fishing grounds is made to drop abruptly in steps of $1^\circ - 2^\circ$, and with this change the area of the fishing grounds shrinks and the fishing season draws to a close. The year 1932 provided the most severe example of the coming of these autumn lows shortening the fishing season and cutting down the total catch. This southward retreat of the favorable water temperatures and the corresponding development of the cold currents (flowing southwest) bring the southward movement of the saury.

x x x x x

(6) Data for the prediction of the abundance or scarcity of skipjack in the Northeastern Sea Area

a. There is a tendency for the catch rates in the Northeastern Sea Area to be poor in years when the winter and spring temperatures are low and good in years when temperatures are high.

Note: In the Zunan and Satsunan sea areas catch rates tend to be good in years with low winter and spring temperatures, and poor in years with high temperatures.

b. The trend of the catch in the Northeastern Sea Area does not necessarily coincide with the rise and decline of the catch in the Satsunan and Zunan Sea areas.

Note: The yearly variations in the catches of the Satsunan and the Zunan areas resemble each other.

c. In the Northeastern Sea Area the abundance or scarcity for the season can to a certain extent be estimated from the amount of fish taken up to the end of June,

and an even better evaluation can be made from the amount taken through July (20 to 50 percent of the year's catch).

d. In the Northeastern Sea Area, in years when the water temperatures are high during the winter and summer up until July, the bulk of the catch is taken in July, but in years when the temperatures are low, the main catch is made in August and September. If temperatures are low during September and October, the fishing season ends early, and if the temperatures are high during these months, the season is prolonged.

e. In years when the temperatures are low in the Northeastern Sea Area, the skipjack schools remain for long and school densely in the southern sea areas, but the number of fish that move into the northern areas is comparatively small.

f. The trend for the fishing season in Miyagi Prefecture to reach its peak later and to end earlier in successive years is paralleled by a drop in the water temperatures at Enoshima as averaged by five-year periods. (Table of water temperatures and dates of the fishing season in Miyagi Prefecture)

Note: (a) In the Northeastern Sea Area in years of abnormally low water temperatures (1931 and 1934), the main summer fishing grounds are located to the south, not moving north of the waters off Kinkazan, and they are far offshore. In such years fishing in the northern sea areas is poor, but in the southern sea areas it is comparatively good because the schools remain there for a long time.

(b) In years of abnormally high water temperatures (1933 and 1937), the fishing grounds reached their farthest north position (42° N. latitude), and the fishing was better in the northern than in the southern sea areas. In such years first catches come early, the end of the fishing season is delayed, and the fishing season is generally prolonged, producing a large catch for the year.

(c) Past years of high and low August surface water temperatures were as follows:

1930 high (approaching 1933)
1931 low (approaching 1934)
1932 high
1933 abnormally high
1934 abnormally low (period of low temperatures continuing much longer than in 1931)

Lowering of the Water Temperatures and Lag in the Skipjack Season in Miyagi Prefecture

5-year Averages	Deviation from water temperatures of normal years at Enoshima (°C)					Deviation from skipjack catch of normal years at 5 ports in Miyagi prefecture (%)						
	Average for Jan. Feb. Mar.	Average for Apr. May June	Average for July Aug. Sept.	Average for Oct. Nov. Dec.	Average for year	May	June	July	Aug.	Sept.	Oct.	Nov.
1918-22	+0.8°	+1.1°	+1.2°	+0.9°	+0.9°	-0.2	+14.0	-10.6	-1.5	-8.1	+5.6	-0.1
1923-27	-0.7	-0.8	-0.3	-5.0	-0.4	-0.1	+0.8	+0.6	+0.3	+1.8	-3.4	+0.1
1928-32	-0.4	-0.9	-0.5	0°	-0.4	-0.2	-7.0	+5.	-2.3	+4.9	+1.5	-0.4
1933-37	-0.9	-0.4	-0.5	-1.2	-0.8	0	-7.7	-0.7	+4.	+3.8	-0.8	-0.5

1935 low
1936 average
1937 abnormally high
1938 high (period of high temperatures continuing longer into the autumn than in average years)

Note: In August of past years, the farthest north limit of the warm water zone of 20° to 22° temperatures reached its farthest north position in 1933 and in 1937, and was at its most southerly position in 1934.

(7) Skipjack Landings at Five Ports in Miyagi Prefecture (%)
(Ishinomaki, Shiogama, Onagawa, Watanoha, Kesennuma)

Month	Year									
	1929	1930	1931	1932	1933	1934	1935	1936	1937	1938
May	0.03	0.10	0.04	0.06	0.10	0	0.02	0	7.80	0
June	3.00	4.60	7.30	6.30	3.40	4.90	1.10	1.10	4.30	1.92
July	23.80	47.50	37.70	38.60	39.10	26.30	19.50	25.60	33.00	18.20
August	43.10	22.00	27.10	31.70	25.90	41.50	39.20	36.10	27.70	32.00
September	18.50	21.00	23.20	21.30	29.10	23.00	28.70	29.10	18.10	31.10
October	1.34	4.40	4.18	1.60	2.30	3.80	11.10	7.70	7.70	16.50
November	0	0.02	0.08	0	0.001	0.04	0.10	0	0.07	0.03
Total number of fish	7,790,348	9,779,498	12,137,977	6,322,290	12,047,403	8,130,625	8,952,218	23,713,140	17,765,533	16,141,694

Notes: (1) 1936 occupies the first place in terms of number of fish, but most of the catch was small (under 4 pounds) skipjack, averaging around 2.5 pounds.

(2) According to a proverb "When there are many small skipjack, the next year will bring a big catch."

(8) On the migrations of the skipjack schools

The following is an outline of the ideas of Technician Uda of the Central Fisheries Experiment Station concerning the migrations of the skipjack as revealed by the shifts in the month of greatest catch (see the following table) in the waters extending from the Satsunan Sea Area to the Northeastern Sea Area.

a. Schools of small skipjack (under 4 pounds in weight)
The main group starts out from the Satsunan Sea Area in May, passes through the waters off southern Japan, and arrives in the Zunan Sea Area chiefly in June and July. These fish advance into the Northeastern Sea Area in August and September. There is in addition a second group of small skipjack which starts out from the Zunan Sea Area at about the same time that the other group originates in the Satsunan Sea Area. This latter group arrives in the Northeastern Sea Area in May and June.

b. Schools of medium-sized skipjack (weight from 4 to 8 pounds)
There is a main group which originates in the Satsunan region in March, shifting the center of its group of schools to the Nankaidō Sea Area in April, and to the Zunan and Northeastern Sea Areas around July. There is thought to be a vaguely defined second group of medium-sized skipjack which originates in the Zunan Sea Area in April and reaches the Northeastern Sea Area in May. It appears that the catch of medium-sized skipjack in the Satsunan Sea Area around September is due to a return of part of this latter group to the southwest.

c. Schools of large skipjack (weight over 8 pounds)
These schools appear centered in the Satsunan Sea Area in May, and thereafter move north, appearing in the Zunan Sea Area in July and in the Northeastern Sea Area in July and August. (A part of this group remains in the Satsunan Sea Area, and the peak catch in that area is also in July.) A second peak in the catch in the Zunan Sea Area in May indicates that there is a second source of large skipjack in that sea area. (Of course, there must be many small skipjack which become medium skipjack and medium skipjack which become large skipjack by growth during the course of the migration. This should particularly be taken into account in sea areas where there is an abundant supply of natural food).

To sum up the foregoing, each of the schools which passes through the Satsunan and Zunan sea areas to come into the Northeastern Sea Area belongs to a group of schools which moves from south to north in spring and early summer, and returns to the south again in late summer and early autumn. These fish are thought to belong to two great migratory groups which have their origins in the Satsunan and Zunan areas and which are, for the most part, made up of medium-sized skipjack.

In addition to these widely migrating schools there are thought to be others, made up for the most part of large and small skipjack, which remain in the southern sea areas as local groups of schools, making small migrations centered around islands and shoals. In other words, it is believed that the schools which make long migrations to the north and those which make short migrations in the south meet in the vicinity of the Zunan Sea Area, the former being composed chiefly of medium-sized skipjack while the latter is made up principally of large and small fish.

The skipjack which migrate into the Northeastern Sea Area are chiefly those in the prime of maturity, and it is thought that the pursuit of feed is the main objective of their migration to the north. (This in view of the fact that the spawning grounds and the nursery grounds for the juvenile fish are in the warm-water areas of the south.) The route of their migration, judging from the movements of the fishing grounds, bears a close relationship to the extension of the warm current and its branches. It is believed that the center of the fishing grounds moves in the direction of the locus of the most curved portion of the isotherms of the warm current system. Even in the case of "descending skipjack" the path of the migration is probably determined chiefly by the patterns of withdrawal of the branches of the warm current and extension of the cold currents to the south. From this point of view it seems appropriate to believe that there are two routes for the descending skipjack, one close to shore and the other farther out to sea. This is in fact the case.

It is believed that there are no skipjack which remain throughout the year in the waters off the Sanriku region. This is indicated by the fact that the high-temperature water areas with temperatures of 20° or higher, where skipjack fishing grounds occur in the summer off the Sanriku region, change for the most part in the winter to cold-water areas having temperatures of less than 5°. Such a change in hydrographic conditions would probably be difficult for a warm-water fish like the skipjack to endure, and it is presumed to be unsuitable for spawning and the growth of juvenile fish.

Furthermore, this view is strengthened by the fact that in actuality skipjack schools are not seen in this sea area during winter, nor are they caught there (they are taken rarely on the longlines of the winter tuna fishery in the warm-water area far to the east, but are hardly to be seen off Sanriku).

(Table of the month in which the peak of the catch of each size of skipjack occurs [number of fish and number of times in percentages])

Notes: On the skipjack which are taken in the winter longline fishery for tuna. The skipjack which are taken in small numbers together with albacore by vessels of this prefecture from late winter to early spring: (a) are taken from November to the first part of April of the following year, being most commonly taken from December to March, and being particularly numerous in March; (b) fishing grounds are the same as those for albacore (a report on albacore will be published at a later date); (c) catches are made at surface temperatures of 17° to 22°, a 5° spread; the most favorable temperatures are 18° to 19°, the same as for albacore; (d) the fish are all of large size, occasionally attaining a weight of 40 pounds. Such fish are taken at this season on longline gear east of Cape Nojima at depths of less than 50 fathoms under the same oceanographic conditions in which albacore are taken, but such questions as which stock these "year-round skipjack" belong to and why they pass the year in northern waters must wait upon data to be gathered in the future. The fact is simply recorded here for future reference.

This paper is based to a large degree on the published researches of Technician Uda of the national fisheries experiment station, and is also based on the ideas of Technician Aikawa of the same station. I take this opportunity of expressing my thanks to these two persons.
(Technician Takeo Sasaki)

Month of Peak Skipjack Catch (Percent of Number of Fish and Number of Times)
(Illustration drawn from 1933)

Catch	Satsunan		Nankaidō		Zunan		Northeastern	
	Number of fish	Number of times	Number of fish	Number of times	Number of fish	Number of times	Number of fish	Number of times
Large fish	5 (7)	5 (7)	--	--	7 (5)	7	7	7 (9)
Medium fish	9 (3)	9 (4)	4	4	7 (4)	7 (4)	7 (5)	7
Small fish	5	5	5	5	6 - 7	7	5 - 6(9)	5 (9)

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On the Stock of Skipjack

by

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From the results obtained by Uda and Tsukushi1/ in studying by month and by area the composition of the catch in terms of large, medium, and small fish, it can be thought that the skipjack that are taken in the waters adjacent to Japan migrate from south to north through the spring and summer and retreat southward in the autumn; that they consist of two strains, one originating in the Satsunan area and one in the Zunan area; and that in the Hokkaido-Sanriku Sea Area there are probably only migrating schools, with no permanently resident schools, while in the Zunan and Satsunan sea areas there are, besides these north-south migrating schools, sedentary local schools which make only small migrations. Okamoto2/, studying the body-weight composition of the catch by months and areas, inferred that in the areas of the Satsunan and Ogasawara islands the schools composed chiefly of young fish under 2.9 pounds or of mature fish over 4.6 pounds remain as sedentary fish, and that the medium sized fish of 2.9 to 4.6 pounds, which can be regarded as being of roughly the same age group (fourth-year fish), are those that around May and June come from somewhere and appear densely congregated off Shikoku, in the Kumano Nada, and off Zunan, and then from July to October move into the Northeastern Sea Area. Aikawa3/, studying the condition factor of skipjack schools, found that in the Ryūkyū Sea Area the schools with a condition factor under 20 remain in the vicinity of islands and shoals, while the schools with a condition factor

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1/ Uda, Michitaka and Jiro Tsukushi: Local Variations in the Composition of Skipjack Schools. Bull. Jap. Soc. Sci. Fish 3 (4), 1934.

2/ Okamoto, Gorozo: On the Weight Composition of the Skipjack Schools of the Northeastern Sea Area. Bull. Jap. Soc. Sci. Fish 9 (3), 1940. (Translated in FWS Special Scientific Report Fisheries No. 51 - Japanese Skipjack Studies).

3/ Aikawa, Hiroaki: A Study of the Skipjack Schools. Bull. Jap. Soc. Sci. Fish. 6 (1), 1937.

of over 20 show no selectivity in their distribution, and that in the Northeastern Sea Area, too, the schools with a factor of under 20 are taken in the greatest numbers along the Ogasawara chain and the Zunan archipelago, although they are also taken on the Sanriku coast. He found further that in the schools of fourth-year fish having a condition factor over 20, the average body-length and the average condition factor in the two areas are in approximate agreement, and the variations from year to year in the average body-lengths in the schools of fourth-year fish having a condition factor of over 20 are in agreement for the two areas, however, in the case of those under 20 they are not in agreement. Taking these facts into consideration, he concluded that in the Northeastern Sea Area the schools with a condition factor of over 20 are of the Ryūkyū strain, and those under 20 are of the Ogasawara strain, and that on the average for 1934, 1935, and 1936 the Ryūkyū strain were 80 percent and the Ogasawara strain were 20 percent of the catch. According to the views of the persons cited above, among the skipjack schools that migrate into the Northeastern Sea Area, those from the Ogasawara and Zunan Sea Areas are comparatively few, and the major part of them either come north from the Satsunan Sea Area, or else are fish which have moved north after first coming from somewhere to congregate densely off Shikoku, in the Kumano Nada, and off Zunan. However, these points need to be gone into a bit further.

If we try to summarize the body-weight composition by fishing grounds, as studied by Kimura[4/] from the skipjack catch, we see (table 1) that the composition varies considerably from one ground to another, but in general small fish are numerous around the islands off Japan proper, while large ones are more numerous around the islands to the south of Japan. Furthermore, medium-sized fish are especially scarce in the Satsunan area and especially plentiful in the northeast, and it appears at first glance as if they moved north from Satsunan to the Northeastern area, but if we compare the age composition inferred for the Satsunan fishing grounds from the graph of body-length distribution given by Aikawa[3/] with the age composition for the Northeastern grounds obtained by Okamoto[2/] (table 2), one can think that probably a part of age-group IV and almost all of age group III and below migrate along the Kuroshio to the waters off northeastern Japan. It is hard to determine, however, whether they come first to Satsunan and then move north from there to the northeast through the waters off Japan proper, or whether only a part of them go to Satsunan while the main body of them go into Kinan, moving north from there through the waters off Japan proper, with a part of them turning south along the way but with most of them continuing on to the waters off northeastern Japan.

4/ Kimura, Kinosuke: The Skipjack Fishing Situation. Papers on the Fishing Situation for the Important Species of Japan, Part I. Lectures on Fish. Tech. and Eng., Vol. 4, 1941.

Table 1. Weight composition by fishing grounds

Fishing ground	Period	Body weight		
		Large (over 8.27 lbs)	Medium (4.13-8.27 lbs.)	Small (under 4.13 lbs)
Truk	1936-1939	$.54_3$	$.37_5$	$.08_2$
Saipan	1935-1939	$.26_0$	$.55_8$	$.18_2$
Palau	" "	$.33_8$	$.32_6$	$.33_6$
Satsunan	1932-33,1936-39	$.25_3$	$.21_5$	$.53_2$
Kinan	" "	$.02_2$	$.52_0$	$.45_8$
Izu Islands	" "	$.02_2$	$.48_5$	$.49_3$
Ogasawara Is.	1937-1939	$.08_0$	$.42_3$	$.49_7$
Northeastern	1932-33,1936-39	$.07_2$	$.66_8$	$.26_0$

Table 2. Age composition by fishing grounds

Fishing Ground	Period	Age*					
		I	II	III	IV	V	VI
Satsunan	1934 - 36	.002	.101	.324	.386	.179	.008
Northeastern	1935	.03	.11	.75	.10	—	—

*Note: Fish with 1, 2, 3, ... annuli are given as I, II, III...

According to Uda[5], the number of fish taken on a single pole during one hour depends on how well the fish bite and on the density of the school, and these in turn differ according to what the school is associated with. The distribution of the things with which skipjack schools may be associated varies by type (1), and therefore even though we assume that a school moves to the Northeast from Satsunan, its character as an object of fishing effort will differ with the difference in fishing ground. Furthermore, the catch per pole per day of fishing depends on the size of the schools and the density of their distribution, and therefore, on the general density of fish; as an index of the density of fish the number of fish taken per pole per day of fishing, divided by the number taken by one pole in one hour, may be used. The total of fish in a sea area is the product of the surface of the area, the density of fish, and the duration of the fishing season. If the total is divided by the average length of the period from the time the schools come into the area until they leave it, that is, the period of their stay, the total number of fish which migrate into the sea area during one fishing season can be obtained. As a measure of the average duration of the stay there should be no objection to taking the maximum value of the number of days elapsing between release and recapture in tagging experiments.

Therefore, if we get the number of fish caught per pole per hour from the reports of surveys of skipjack grounds by research vessels published in the Reports of Oceanographic Investigations[6], and the number of fish caught per pole per

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5/ Uda, Michitaka: The Shoals of "Katuwo" and Their Angling. Bull. Jap. Soc. Sci. Fish. 2 (3), 1933. (See p. 68)

6/ Parts published in (58) - (67)

day of fishing from the Reports of Investigations of the Fishing Situation by Special Reporting Vessels, and the maximum number of elapsed days from the records of recaptures published in the same Reports[7], and estimate the area of the fishing grounds by counting the number of 1^{o} squares in which catches were made as shown on the charts of the fishing grounds appended to the oceanographic charts published by the Central Fisheries Experiment Station, and infer the number of months of the fishing season from the number of fish landed per 10-day period as given in Kimura's study[4], and then attempt to compare by the method described above the number of fish that migrate into the various fishing grounds (table 3), it can be thought, as Okamoto[2] imagined, that the majority of the fish of age-group III come directly to Kinan without passing through the Satsunan area and from there move north to the Northeastern Sea Area through the waters off Japan proper.

Now if we assume that the above hypothesis is correct, in the age composition on the southern fishing grounds the fish of age-group III should show a gradual decrease in the late spring and a gradual increase in the late autumn. However, according to Aikawa[3] (table 4), the body-weight of fish of age-group III is 1.60 - 3.45 kg; if we try to bring in the results of his measurements of the annuli in the vertebrae (table 5), since it appears that the annuli develop from winter to summer, it can be considered that the body-weight of fish of age-group III is 3.7 pounds in early spring and 7.4 pounds in late autumn, while the weight of fish of age-group IV is around 8.27 pounds early in the spring. For this reason, in the composition by large, medium, and small sizes, traces of a recurrence of age-group III can be expected in late autumn but not in early spring. On the Palau fishing grounds studied by Kimura[4], in the peak fishing seasons of spring and autumn, there is clearly discernible in the age composition (table 6) a gradual increase of the medium-sized fish of age-group III in late autumn.

If we assume in this way that after the skipjack have spent their juvenile period in the region of the South Sea Islands they make their great migration north along the Kuroshio, part of them as fish of age-groups II and IV but the majority of them as age-group III, and that thereafter they remain in southern waters, it goes without saying that we must go by the composition on the South Sea fishing grounds in calculating the survival rate, which is one of the important characteristics

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7/ Parts published in (54), (57), (59), (61), and (63).

Table 3. Numbers of fish migrating into each fishing ground

Ground	Number per pole per hour* (a)	Number per pole per day's fishing* (e)	Number of 1° squares in which fish were taken (A)	Number of months in which fish were taken (T)	Maximum number of days from release to recapture (t)**	Number of fish present $\frac{eAT}{At}$	Number of fish present Age-groups II	III	IV
Satsunan	19.5	9.2	20	12	20	5.7	.6	1.8	2.2
Kinan	33.7	21.7	50	8	14	14.1	--	--	--
Izu Is. Ogasawara	40.4	15.6	50	11	18	11.8	--	--	--
Northeast	45.4	27.2	150	7	38	10.8	1.2	8.1	1.1

Notes: *Average of the averages for each year 1936-40.
**According to the point of recapture.
/ Figured from the age composition in table 2.

Table 4. Body length and weight by ages

Age	Body length	Body weight*
	cm	kg
0	— 26	— .34
I	26-34	.34- .75
II	34-43	.75-1.60
III	43-54	1.60-3.45
IV	54-64	3.45-5.74

*Note: Inferred from the body length by using the length-weight curve.

Table 5. Radius (r mm) of each annulus in the vertebral centrum and total diameter (T mm) in August

Age	r_1	r_2	r_3	r_4	T
I	2.60	—	—	—	3.70 (1)
II	2.51	3.76	—	—	4.69 (7)
III	2.59	3.96	5.38	—	6.21 (8)
IV	2.60	3.95	5.48	7.20	8.02 (4)
Average	2.57 (20)	3.88 (19)	5.41 (12)	7.20 (4)	—

Note: ( ) is the number measured

Table 6. Size composition by months on the Palau fishing grounds

Month	Large	Medium	Small
April	.328	.254	.418
May	.318	.194	.488
June	.240	.378	.382
October	.408	.232	.360
November	.380	.304	.316
December	.334	.404	.262

Note: Figures for April, May, and June are the average for 1935-39; those for October, November, and December are the average for 1934-1938.

of the skipjack stock. If we seek the survival rates* from the ratio of large and small fish for the Truk and Palau grounds by the same method as was previously[8/] followed with the black tuna, yellowfin tuna, and albacore, they come out as .58 and .50 respectively. On the other hand, in late autumn the only medium-sized fish are those of age-group III and the large fish are of

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* Since medium-sized fish are 1.88 - 3.75 kg, they include $\frac{3.45 - 1.88}{3.45 - 1.60} = .85$ of age group III and $\frac{3.75 - 3.45}{5.74 - 3.45} = .13$ of age-group IV. The large-sized fish are those over 3.75 kg, so 1 - .13 = .87 of age-group IV and all of age-groups V and up are included. Consequently, taking p as the survival rate,

$$\frac{\text{large}}{\text{medium}} = \frac{.87\,p + \frac{p^2}{1-p}}{.85 + .13p}$$

, and since this value is 1.45 at Truk and 1.04 at Palau, the values of p will be $.58_4$ and $.50_4$, respectively.

8/ Tauchi, Morisaburo: On the Stock of Black Tuna. Bull. Jap. Soc. Sci. Fish. 9 (4), 1940; On the Stock of Yellowfin Tuna, loc. cit.; On the Stock of Albacore, loc. cit. (Translated in FWS Special Scientific Report - Fisheries No. 16 - Three Papers on the Stocks of Tuna in Japanese Waters.)

age-groups IV and above, so if we seek the survival rate from the composition at Palau during the autumn peak season by the method previously[9] used for the yellowtail, it comes out .54.**

For those species of the tunas which have roughly the same range of distribution and which resemble each other in making large seasonal migrations, for which estimates have hitherto been made, the survival rate is .75 for the black tuna, .57 for the yellowfin tuna, and .66 for the albacore[8], but if we take into consideration the fact that the highest age-group in the catch is VI[3] for the skipjack, while it is X for the black tuna, IX for the yellowfin, and VIII for the albacore, we can probably say that the value obtained above as the survival rate for the skipjack is fairly reliable.

Effective clues for the deduction of the catch rate are found in the records of tagging experiments. With the skipjack, 318 fish were released from 1934 to 1939 in the Satsunan area, 10 in the Kinan area, and 162 in the Izu archipelago of which 7, 1, and 2 respectively were recaptured within 20 days and close to the point of release, while of 92 fish released in the Ogasawara area two were recaptured 53 and 58 days later in the Northeastern region. In the same period, 1,310 fish were released in the Northeast, but not one of them was recaptured[10]. Accordingly, the proportions recaptured are .022 for Satsunan, .100 for Kinan, .012 for Zunan, and .0014 for Ogasawara-Northeast. Since not one of the fish released in the Northeastern Sea Area was captured, it can be seen that the nearer the fish are to the northern extremity of their migration, the stronger is the effect of the handling in connection with capture and tagging. It is thought, therefore, that it is inappropriate to use the rate of recapture to establish the catch rate for Ogasawara-Northeast. Then if we divide the number of fish taken by the number that migrate into the area to get for each fishing ground a numerical value in

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** If we take ρ as the survival rate, then $\frac{\text{large}}{\text{medium}} = \frac{\rho}{1-\rho}$

and this is $\frac{.374}{.313} = 1.19$ so $\rho = \frac{1.19}{2.19} = .54_3$.

9/ Tauchi, Morisaburō: On the Stock of Yellowtail. Bull. Jap. Soc. Sci. Fish. 9 (4), 1940.

10/ The records of taggings are in Reports of Oceanographic Investigations (54), (55), (57), (58), (59), (61), (63), (65), and the records of recapture are in (54), (57), (59), (61), (63).

direct proportion to the catch ratio and calculate the catch rate for Japanese waters on the basis of the proportion of recaptures on the grounds south of Ogasawara, we get .10 - .30.***

The above value does not seem too unsuitable as a catch rate for skipjack in view of the rates of .10 for black tuna and .29 for yellowfin that have been deduced previously.[8]

To summarize the above: (1) After the skipjack have spent their juvenile period in the region of the South Sea Islands, they make a great migration beginning in early summer along the Kuroshio through the waters off Japan proper, part of them as fish of age-groups II and IV but most of them as age-group III. After reaching the waters off Northeastern Japan, they turn back south with the autumn and thereafter appear to remain in southern waters; (2) their survival rate can be considered to be about .54 and their catch rate between .10 - .30.

*** According to Kimura [4] the average numbers of fish caught 1937-39 were 5,440,000 in Satsunan, 6,590,000 in Kinan, 5,440,000 in Izu-Ogasawara, and 29,060,000 in the Northeast, so the proportions for the fishing grounds Satsunan:Kinan:Izu-Ogasawara:Northeast are $\frac{544}{5.7} : \frac{659}{14.1} : \frac{544}{11.8} : \frac{2,906}{10.8} \doteqdot 2:1:1:5.$ But the proportion caught on the fishing grounds from Ogasawara south is .134 so that from the waters adjacent to Japan, including the Northeast, is $.134 \times \frac{9}{4} \doteqdot .30$. If an inference is drawn on the basis of the Satsunan and Izu-Ogasawara areas, leaving out Kinan, where so few fish were released, $.034 \times \frac{9}{3} \doteqdot .10$. Consequently, if we assume that the skipjack in the waters adjacent to Japan move northward from Satsunan to the Northeast, it means that the catch rate in the waters adjacent to Japan proper is .10 - .30.

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(English title and synopsis)

Notes on the Shoal of Bonito (Skipjack, Katsuwonus pelamis) along the Pacific Coast of Japan

By Hiroaki Aikawa

SYNOPSIS

(1) Age of bonito was determined on the basis of the vertebral bones just like that of chub-mackerel. The body length[1] of bonito well correlates with the length (T) of the centrum of the vertebral bone (fig. 1). The rings (r) formed on the surface of the centrum can be considered as the year rings. The first ring measures 2.5 mm. in radius, the second one 3.9 mm., the third one 5.4 mm., and the fourth one 7.2 mm. When the body length is 26 cm., the length of the centrum (T) becomes equal to the radius of the first ring (r_1) and thus the ring may be completed. Therefore, the bonito less than 26 cm. in body length may belong to 0-year group. According to the similar assumption, I-year group ranges in body length from 27 cm to 34 cm., II-year group from 35 cm. to 43 cm., and III-year group from 44 cm. to 53 cm. IV-year group may be larger than 54 cm.
(2) Most of the bonito caught by angling are mainly composed of III- and IV-year groups in the Liu-Kiu region, and III-year group occupies 60% of all and IV-year group 40%. While bonito shoal is simply composed of III-year group in the Tohoku region. It is also remembered that bonito caught by longlines is far larger in size than that by angling and usually belongs to V-year group or far older one. (3) There are two different shoals of bonito in these regions. The one is the migratory shoal and the other the resident shoal. The resident shoal is generally larger in the mean value and in the modal value of body length than the migratory group either in III-year group or in IV-year group. The migratory group is simply composed of III-year group in the Tohoku region, while the resident group comprises to some extent IV-year group. The migratory group is higher than 20 in the quality-indicator ($10^3 \cdot W/L^3$), while the resident group less than 20. In the Liu-Kiu region, the

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[1] Kagoshima Prefecture Fisheries Experiment Station: Reports of Cooperative Studies of the Skipjack Fishery; 358, 1935.

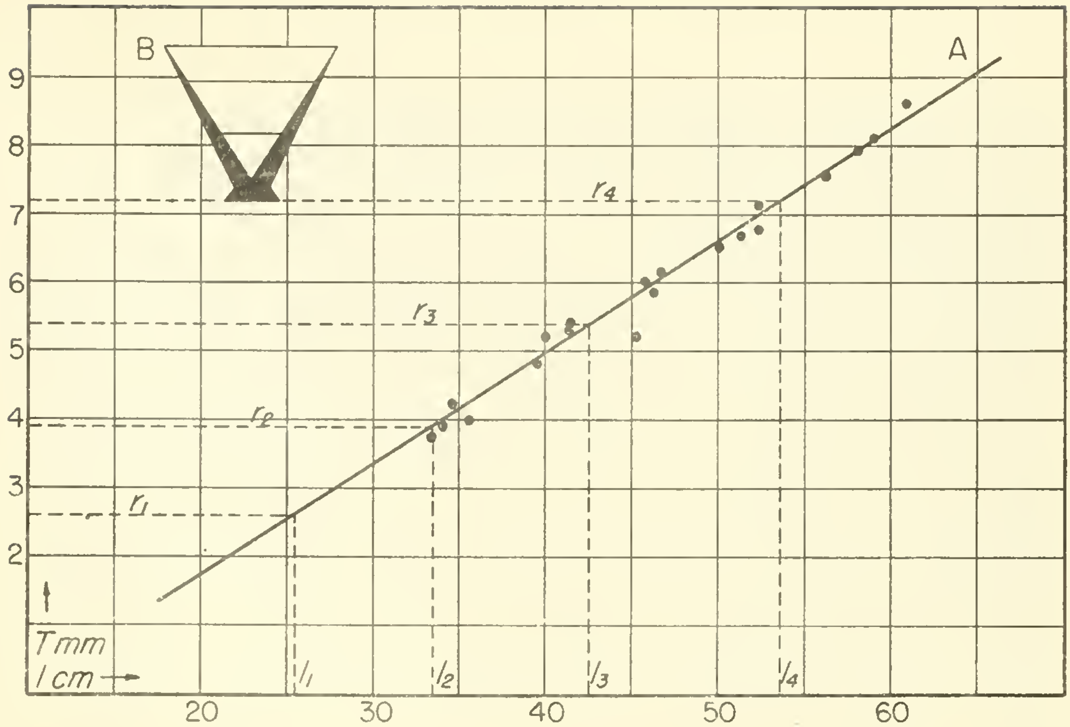

FIG. 1 (A) RELATIONSHIP BETWEEN THE TOTAL LENGTH OF THE VERTEBRAL CENTRUM (T) AND THE BODY LENGTH OF THE SKIPJACK (l). $r_1 - r_4$ ARE THE RADII OF THE ANNULI, $l_1 - l_4$ ARE THE DEDUCED BODY LENGTHS AT WHICH EACH ANNULUS WAS COMPLETED. (B) SKETCH SHOWING r AND T.

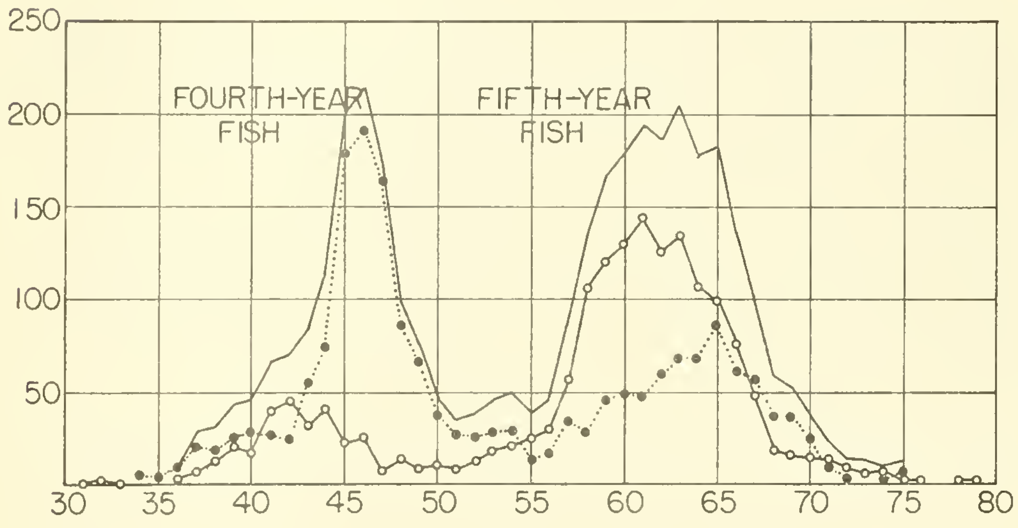

FIG. 2 BODY LENGTH DISTRIBUTIONS OF MIGRATORY SCHOOLS (WHITE DOTS) AND SEDENTARY SCHOOLS (BLACK DOTS) (SUMMARY OF 1934 - 1936). THE HORIZONTAL AXIS IS THE BODY LENGTH (CM) AND THE VERTICAL AXIS SHOWS THE NUMBER OF FISH.

resident group is fished principally in the area around the small isles and over the shallow banks. The resident group is also related with small isles of the Bonin Chain, although it can migrate north-eastwards into the open sea of the Tohoku region. On the other hand, the migratory groups are fished in any portion in both regions. (4) The migratory shoal of III-year group in the Tohoku region is probably originated from the migratory shoal of III-year group in the Liu-Kiu region, because shoal of similar character to those in both regions can be fished in the Seinan region. The migratory shoal of III-year group can be called the Liu-Kiu group both in Seinan and Tohoku regions. While, the resident groups in both regions show no similarity in any respect to each other. In addition, no resident shoal is fished in the Seinan region between these two regions. According to the distribution of the fishing positions, the resident shoal seems to migrate into the Tohoku regions from the southern sea through the Bonin Chain. Therefore the resident shoal can be considered as the Bonin group in the Tohoku region. The migratory shoal occupies 60% of total catch and the resident shoal 40% in the Liu-Kiu region. In the Tohoku region, the Liu-Kiu group occupies 80% of total catch and the Bonin group only 20%. (5) The fluctuation in the yield of these regions seems to be influenced by the changes in the age composition in the Liu-Kiu region, and also in the ratio of the resident group (the Bonin group in the Tohoku region) to the migratory group (the Liu-Kiu group in the Tohoku region).

(end of English synopsis)

Since 1934 the Central Fisheries Experiment Station has been carrying on a study of the skipjack catch in conjunction with the fisheries experiment stations of the various prefectures. In order to study the causes of fluctuations in the catch, it is necessary to assemble statistical data and also to learn the biological characteristics of the fish, such as life history, migrations, age composition of the schools, and the types of schools. As preparation for the catch study the age of the skipjack was determined using vertebrae and the age composition of the catch was found, and deductions were made as to what kind of biological groups compose the skipjack population of the Pacific coast of Japan.

The Skipjack Schools of the Ryūkyū Sea Area

1. Body-length distribution. The skipjack of this sea area are divided into three categories by size, large, medium, and small. In the catch of the Hyuga Maru, the Shoyo Maru, and the Zunan Maru, which fished in this area in 1934, there was a mixture of large, medium, and small-sized fish, with large and small fish plentiful while medium-sized fish were few (table 1).

Table 1. Proportions of large, medium, and small skipjack in the catch (1934).

Fishing grounds	Large	Medium	Small	Number of fish
	%	%	%	
northern shoal	27.1	15.9	57.0	12,900
northern offshore	21.5	8.5	70.0	9,300
southern shoal	47.2	9.4	43.4	10,600
southern offshore	84.5	9.3	6.2	34,300
whole Ryukyu area	58.5	10.4	31.1	67,100

The proportions varied geographically, small fish being more numerous than large ones on the fishing grounds north of Okinawa and the opposite situation prevailing on the southern grounds with large skipjack more plentiful. According to the report of of Kagoshima Prefecture Fisheries Experiment Station for 1935[1/], the average proportions of the three sizes in the catch for the six years from 1928 to 1933 were 18% large, 29% medium, and 52% small. These differ from the proportions in the 1934 catch, but this is thought to be due to the fact that the distinction between the three size categories is not drawn on any definite standard rather than to a change in the composition. If we look at the distribution (fig. 2) of body lengths of the skipjack that are taken, we can perceive a small size group with its mode at 46 cm. and a large size group having its mode at 63 cm.

2. <u>Age of skipjack</u>. It is difficult to use the scales and otoliths for determining the age of skipjack. There are rings formed on the centra of the vertebrae. The number of these rings is extremely great, some are broad and some are narrow, some are perfectly and others imperfectly formed, and they are densely or sparsely distributed. Now some areas can be recognized through the density or sparseness of the distribution, and on the boundaries of each area where the rings are densely distributed there are thick and perfectly formed representative rings. Using the first to fifth vertebrae, measurements were made on the surface of the cross section of the distance from the center of the centrum

1/ Kagoshima Prefecture Fisheries Experiment Station: Reports of Cooperative Studies of the Skipjack Fishery, 358, 1935.

to each representative ring, that is, the radius (r) of the annulus, and of the distance from the center to the outer edge of the centrum, that is, the total length (T) of the centrum (table 2). There is room for individual error in the selection of the representative annuli, but the fact that this error is very small is clear from a consideration of the standard deviation of the radius of each ring, as shown in table 2. There is, as shown in figure 1, a definite correlation between the body length (l) of the skipjack and the total length of the centrum (T) at the time. Consequently every ring can be tentatively taken as an annulus. Each ring is completed when the total length T is equal to r. In other words, it can be thought that when $T_n = r_n$, the body length is l_n, and at this time the skipjack has completed n years since hatching. Skipjack complete the first ring (r_1) at a body length of 26 cm., the second (r_2) at 34 cm., the third (r_3) at 43 cm., and the fourth (r_4) at 54 cm. Skipjack with a body length of less than 26 cm. are first year fish (0-year group), those from 26-34 cm. are second-year fish (I-year group), 34-43 cm. are third-year fish (II-year group), 43-54 cm. are fourth-year fish (III-year group), and those over 54 cm. are[2] fifth-year (IV-year group). In the catch from the pole and line fishery there are no fish under 30 cm. nor over 80 cm., and the main part of the catch is from slightly over 43 cm. to slightly over 67 cm. The group of small fish with its mode at 46 cm. is between 40-50 cm. and clearly consists of fourth-year fish, and the large-sized group between 55-70 cm. are fifth-year fish. On the average in the three years 1934-1936 fourth-year fish and fifth-year fish were taken in the proportion of 48.9% and 61.1% respectively (table 3), which is in approximate agreement with the ratios of large and small skipjack in the catch as given in table 1. The medium-sized skipjack include fish which must belong to either the fourth-year or the fifth-year class. From year to year there is more or less of a change in the average body length and the mode of the fourth-year and fifth-year fish (table 4). Furthermore, there are differences in the age composition in different years (table 3). Since this is considered to be one of the important causes of fluctuations in the amount of the catch, hereafter accurate observations must be made of the course of changes in the age composition in addition to accurate investigations of the amount of the catch.

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[2] Large skipjack are occasionally taken on tuna longlines in the winter. A skipjack taken in the middle of December 1936, 43 miles SE/N½E of Nojima Saki (water temperature 19.1°C) at a depth of 30 fathoms had a body length of 81.3 cm. (total length 88.5 cm.) and a body weight of 14.5 kg. Since it was possible to measure up to the 6th ring, it is presumed to have been a seventh-year fish.

Table 2. Actual values of measurements of the radii (r_1 - r_4) of each annulus in the vetebral centrum and total length (T) of the centrum at each body length. (From material at the Yaizu fishmarket in August, 1935)

No.	Body Length (cm)	Body Weight (gr)	Annulus 1		Annulus 2		Annulus 3		Annulus 4		Total length	
			r_1 mm	S.D.	r_2 mm	S.D.	r_3 mm	S.D.	r_4 mm	S.D.	T mm	S.D.
1	61.0	5520	2.6	0.07	3.9	0.20	5.4	0.30	7.4	0.20	8.6	0.44
2	59.0	4800	2.9	0.09	4.0	0.30	5.9	0.42	7.2	0.40	8.1	0.52
3	58.0	4230	2.4	0.12	4.0	0.25	5.2	0.35	7.0	0.35	7.9	0.26
4	56.0	3880	2.5	0.10	3.9	0.18	5.4	0.20	7.2	0.20	7.5	0.28
5	52.0	3020	2.5	0.13	4.0	0.20	5.5	0.25			7.1	0.35
6	52.0	2920	2.6	0.11	4.0	0.30	5.8	0.30			6.1	0.20
7	51.0	2800	2.6	0.08	4.0	0.25	5.6	0.35			6.6	0.40
8	50.0	2410	2.6	0.09	4.0	0.24	5.1	0.30			6.5	0.37
9	47.0	1910	2.7	0.12	3.8	0.34	5.2	0.45			6.2	0.38
10	46.5	1860	2.7	0.13	4.0	0.21	5.2	0.32			5.8	0.35
11	46.0	1950	2.6	0.10	4.1	0.32	5.2	0.28			6.0	0.30
12	45.5	2050	2.4	0.15	3.8	0.25	5.4	0.30			5.4	0.37
13	41.5	1380	2.6	0.12	3.0	0.34					5.3	0.06
14	41.5	1420	2.5	0.10	3.8	0.24					5.4	0.09
15	40.0	1340	2.6	2.20	4.0	0.30					5.2	0.35
16	39.5	1260	2.5	0.18	3.8	0.21					4.8	0.38
17	35.5	840	2.4	0.46	4.0	0.35					4.0	0.35
18	34.5	770	2.5	0.10	3.8	0.35					4.2	0.40
19	34.0	750	2.5	0.10	3.9	0.20					3.9	0.30
20	33.5	720	2.6	0.20							3.7	0.15
			2.6		3.9		5.4		7.2			

Table 3. Age composition of skipjack

Year	Fourth-year fish	Fifth-year fish	Number of fish measured	Total number of fish caught
1934	37.3%	62.7%	2,125	400,700
1935	48.2	51.8	615	265,700
1936	36.8	63.2	1,354	334,100
3-year average	38.9	61.1	4,094	---

Table 4. Changes in the body length of fourth-year and fifth-year fish

Year	Fourth-year fish				Fifth-year fish			
	Migratory		Sedentary		Migratory		Sedentary	
	Average	Mode	Average	Mode	Average	Mode	Average	Mode
1934	44.8	44	46.4	46	61.8	61	62.7	64
1935	43.5	41	47.2	45	64.4	63	63.7	64
1936	42.9	41	43.2	46	62.1	62	63.9	60

3. <u>The condition factor in skipjack</u>. The condition factor is the so-called "quality indicator" ($10^3W/L^3$). Kimura[3/] has used it to find one of the characteristics of sardine populations. The condition factors of the skipjack schools of the Ryukyu Sea Area are broadly distributed between 13-35 (fig. 3) and the differences due to age are slight (table 5). If we divide the schools into those in which the average condition factor, or at least the mode, is under 20 (shown with black circles in all figures) and those in which it is over 20 (shown with white circles in the figures), and then consider the distribution of the positions at which catches were made of each (fig. 4), the lean fish below 20 are taken in large numbers around the small islets and shoals (banks) stretching from Yakushima and Tanegashima to Amami Oshima in the north, and to the south many of them are taken on the shoal grounds between Miyakojima and Kumeshima, but they are generally scarce throughout the offshore fishing grounds northwest of Okinawa. The fat fish, however, are taken at all grounds at the same rate. The proportion of catches made from each group in a three-year total was 21 times for the lean group to 19 times for the fat group on the northern shoal grounds, and 11 times for the lean group to 45 times for the fat group on the central offshore grounds, where the number of catches from the lean group was conspicuously lower. On the southern shoal grounds the proportion of catches from the lean group again increases with 32 catches of lean fish to 20 catches of fat fish. There is no departure from the trend for each fishing ground in any year (table 6). This indicates that the lean schools are somehow closely related to islets and shoals. The skipjack schools of the Ryukyu Sea Area are divided ecologically into the two categories of migratory schools and sedentary schools. In the migratory schools fat schools make up 63%, and in sedentary schools the lean schools make up 68% of the whole (table 6). Accordingly it can be said that the migratory schools are those that have a condition factor of over 20 and have no selectivity within the range of their migrations, while the sedentary schools are those that have a condition factor of less than 20 and reside permanently chiefly in the waters adjacent to islets and shoals. As two or three characteristics which should be added: (1) With the migratory schools, in the total landings for one fishing season the fifth-year fish are more numerous than the fourth-year fish, but with the sedentary schools the opposite is true. (2) In the migratory schools the condition factor of the fifth-year fish is lower than that of the fourth-year fish, but in the sedentary schools it is higher. (3) Both the average and the mode of the body length are greater for the migratory schools than for the sedentary schools (table 7) (sic). However, the difference in

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3/ Kimura, Kinosuke: Bull. Jap. Soc. Sci. Fish 3 (6), 1935.

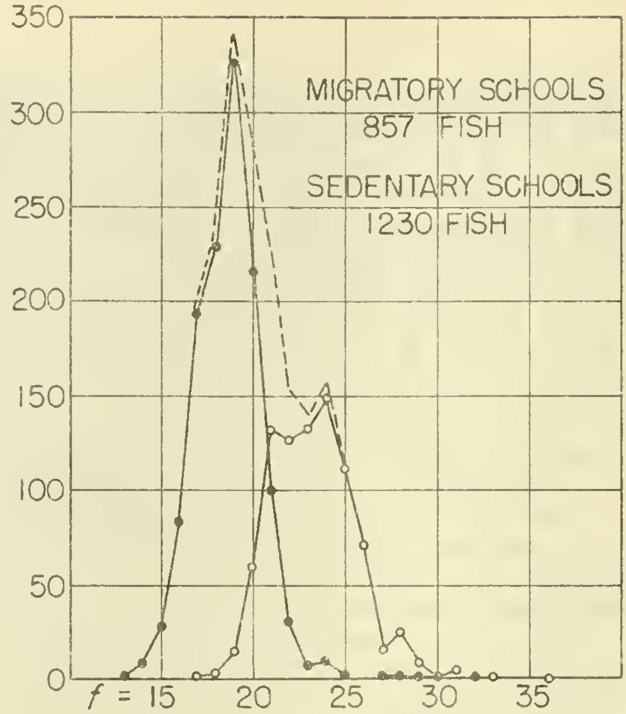

FIG. 3 DISTRIBUTIONS OF CONDITION FACTORS OF MIGRATORY AND SEDENTARY SCHOOLS (RYŪKYŪ SEA AREA, 1934). WHITE DOTS FOR MIGRATORY SCHOOLS, BLACK DOTS FOR SEDENTARY SCHOOLS. THE BROKEN LINE SHOWS THE DISTRIBUTION OF THE CONDITION FACTOR FOR ALL SCHOOLS. HORIZONTAL AXIS IS THE CONDITION FACTOR, VERTICAL AXIS IS THE NUMBER OF FISH.

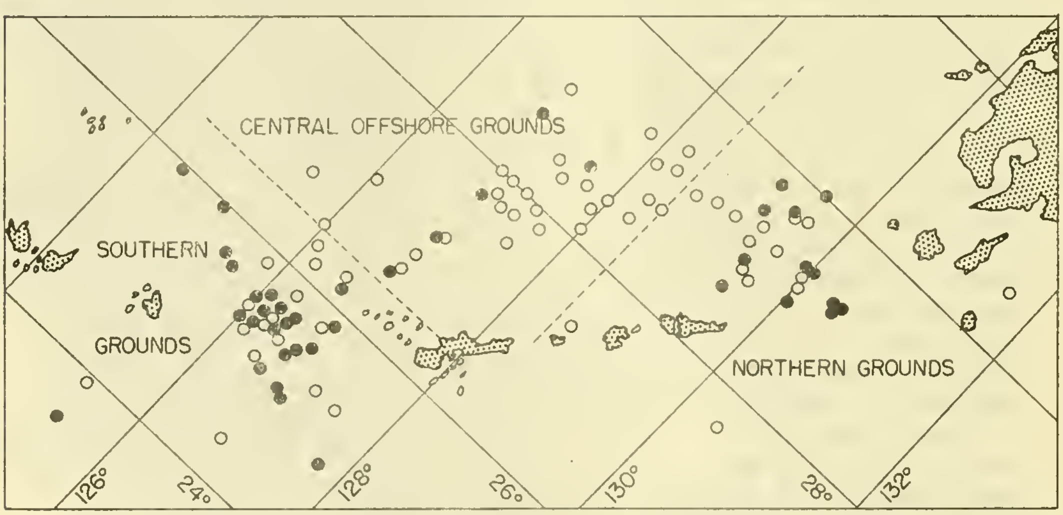

FIG. 4 DISTRIBUTION OF POSITIONS AT WHICH MIGRATORY SCHOOLS (WHITE DOTS) AND SEDENTARY SCHOOLS (BLACK DOTS) WERE FISHED. (RYŪKYŪ SEA AREA, 1934 - 1935)

Table 5. Changes with body length in the condition factor of the two groups in the Ryukyu and Northeastern sea areas (1936)

Age	Body length (cm)	Ryukyu Area		Northeastern Area		Difference in condition factor	
		Migratory	Sedentary	Ryukyu stock schools	Migratory Ogasawara schools	Ryukyu	Northeastern
II	36	22.1	20.5	30.8	---	1.6	---
	37	22.7	19.3	32.8	20.8	3.4	12.0
	38	22.0	18.4	28.4	18.9	3.6	9.5
	39	21.6	18.6	27.1	19.7	3.0	7.4
	40	21.8	19.3	26.6	19.0	2.5	7.6
	41	23.1	19.3	23.6	19.2	3.8	4.4
	42	22.4	20.0	23.4	17.6	2.4	5.8
	43	22.7	20.7	23.3	17.9	2.0	5.4
III	44	22.1	19.2	23.8	18.1	2.9	5.7
	45	21.9	20.0	24.4	17.3	1.9	7.1
	46	22.0	18.6	23.5	18.2	3.4	5.3
	47	20.4	19.1	22.4	17.6	1.3	4.8
	48	21.1	18.0	23.2	17.9	3.1	5.3
	49	24.4	17.0	22.7	18.1	7.4	4.6
	50	24.3	19.9	24.0	19.1	4.4	4.9
	51	27.4	18.0	23.0	18.3	9.4	4.7
	52	28.3	18.8	24.1	18.2	9.5	5.9
	53	24.6	19.0	24.0	18.0	5.6	6.0
IV	54	26.5	19.9	24.4	17.1	6.6	7.3
	55	26.4	19.9	23.2	18.4	6.5	4.8
	56	23.0	18.3	23.5	17.5	4.7	6.0
	57	24.1	18.2	23.3	18.9	5.9	4.4
	58	23.3	16.6	22.5	19.5	5.7	3.0
	59	23.9	17.1	25.3	17.5	6.8	7.8
	60	23.1	19.7	24.8	17.1	3.4	7.6
	61	23.1	19.1	26.5	18.5	4.0	8.0
	62	22.2	20.5	21.3	16.4	1.7	4.9
	63	22.3	19.1		17.6	3.2	
	64	21.8	18.7		17.1	3.1	
	65	23.1	18.9		16.7	4.2	
	66	22.2	19.2		13.2	3.0	
	67	23.0	19.2		16.0	---	
	68	23.1	18.9		15.0	4.2	
	69	21.8	14.3			7.5	
	70	22.9	18.3		20.0	4.6	
V	71	20.7			22.9	---	
	72	22.6	16.0		22.2	6.6	
	73	24.1	21.0			3.1	
	74	21.2	21.5		27.0	0.3	
	75	25.4	18.4			7.0	
	76	21.0	17.7			3.3	
	77	22.9	19.3			3.6	
4th-year fish		23.0	20.7	24.4	18.8	2.3	5.6
5th-year fish		24.0	22.6	24.0	18.0	1.4	6.0
Average		22.9	19.3	24.4	18.8	3.5	5.6

Table 6. Number and percentages of catches made from migratory and sedentary schools on the principal fishing grounds and the percentage of fat and lean schools among them

Year	Type of school	Northern grounds (shoal grounds)			Central grounds (offshore grounds)			Southern grounds (shoal grounds)			Comparison of condition factor					
											above 20			under 20		
1934	migratory	10	times	41.2%	25	times	78.2%	8	times	28.6%	33	times	60.8%	22	times	40.0%
	sedentary	14	"	58.8	7	"	31.8	20	"	71.4	12	"	36.4	21	"	63.6
1935	migratory	4	"	58.0	10	"	83.3	4	"	31.7	13	"	56.5	10	"	43.5
	sedentary	3	"	42.0	2	"	16.7	9	"	68.3	3	"	28.0	10	"	72.0
1936	migratory	5	"	55.6	10	"	83.3	8	"	72.8	24	"	6 .5	11	"	31.5
	sedentary	4	"	44.4	2	"	16.7	3	"	27.2	3	"	27.3	8	"	72.7
Total	migratory	19	"	47.5	45	"	80.3	20	"	38.4	70	"	61.9	43	"	38.1
	sedentary	21	"	52.5	11	"	19.7	32	"	61.6	18	"	31.6	39	"	68.4

Table 7. Comparison of migratory and sedentary schools

Year	Type of school	Condition factor		Age composition		Percentages	Av. condition factor
		4th-year fish	5th-year fish	4th-year fish	5th-year fish		
1934	migratory	25.5	22.9	13.9%	86.1%	40.5%	24.1
	sedentary	19.0	19.1	54.2	45.8	59.5	19.0
1935	migratory	27.3	24.4	55.0	45.0	47.5	25.4
	sedentary	17.6	20.7	46.6	53.4	52.5	19.7
1936	migratory	23.0	24.0	28.6	71.4	38.2	23.6
	sedentary	20.7	22.6	41.7	58.3	61.8	21.9

condition factor between the migratory and sedentary schools is not very great in the third-year fish below 43 cm., but in fourth-year and fifth-year fish, with the increase in age and body length, the difference becomes well marked (table 5). The proportions of the mixture of these two groups of fish should probably also be noted as one reason for the fluctuations in the amount of catch in the Ryukyu Sea Area.

4. Differences in the condition factor and the manner in which the fish take the bait. (table 8). There are seasonal changes in how well the fish take the bait. At the start and finish of the season in spring and fall most of the schools bite well, but during the peak season few of them do. It is hard to find any clear correlation between the differences in the water temperature at the positions where catches were made and the way the fish bite. Where the schools were dense and large the fish generally took the bait well, and where they were sparse and small the fish mostly bit poorly. Perhaps the "panic theory"4/, which explained the relation between herring schools and catch, could be used to explain this circumstance. Furthermore, the sedentary schools with their condition factor of less than 20 generally take the bait well, while the migratory schools, with condition factors of more than 20, generally bite poorly. In a general view, it may be wondered whether the biological characteristics of a school govern how well or how badly the fish in it bite.

The Skipjack Schools of the Northeastern Sea Area

5. Distribution of body lengths and age composition.

The skipjack schools of the Northeastern Sea Area, stretching from the Ogasawara Is. and the Zunan chain to the waters off Sanriku, differ from those of the Ryukyu Sea Area in that the body-length groups are distributed only between 45-55 cm. and in that as far as age groups are concerned, schools of fourth-year fish are abundant and fifth-year fish are extremely scarce (fig. 5).

6. Condition factor. In the Northeastern Sea Area, too, there are two groups that differ in their condition factor (table 5, fig. 6). They are divided into migratory schools with an average condition factor of over 20 and sedentary schools with the factor less than 20; the former are called the Ryukyu stock and the latter the Ogasawara stock. The difference in condition factor between the two groups is more extreme than the difference between the two groups in the Ryukyu Sea Area. Consequently it is thought that the relationship between the two groups of the Northeastern Sea Area is even more distant than the relationship between the two groups of the Ryukyu Sea Area.

4/ Graham, M.: J. du Conseil, 4 (2), 1931.

Table 8. Relationship of the characteristics of the school and the external conditions to how well the fish take the bait (Ryukyu sea area, 1934)

How the fish bit	Kind of school		Condition factor		Comparison of water temperatures on grounds			
	dense-large	sparse-small	over 20	under 20	Month May	Bit well 24.3°C	Bit poorly 23.4°C	All grounds 23.8°C
well	76%	10%	43%	70%	June	26.6°C	26.7°C	26.6°C
average	2	18	4	7	July	29.2	29.7	29.3
poorly	22	72	53	23	August	28.9	28.8	28.8

Season changes in the way the fish take the bait

Month	March	April	May	June	July	August	September	October	Total
well	100%	90%	57%	44%	27%	25%	100%	100%	57 times
poorly	0	10	43	56	73	75	0	0	57 times

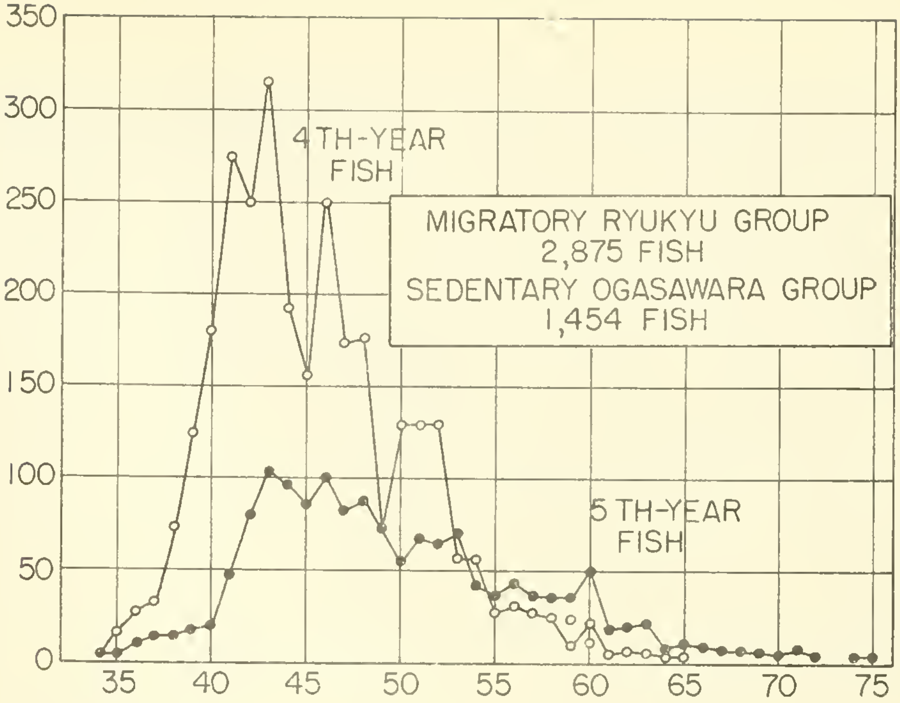

FIG. 5 DISTRIBUTION OF BODY LENGTHS OF THE RYŪKYŪ STOCK (WHITE DOTS) AND THE OGASAWARA STOCK (BLACK DOTS). (NORTHEASTERN SEA AREA, TOTAL FOR 1934-36). HORIZONTAL AXIS IS BODY LENGTH, VERTICAL AXIS IS NUMBER OF FISH.

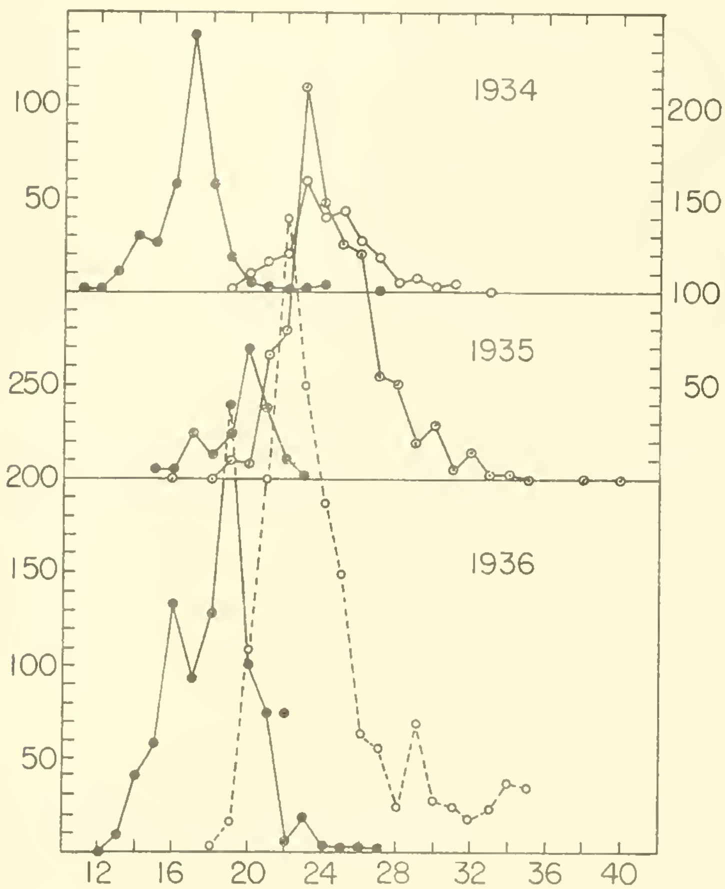

FIG. 6. DISTRIBUTION OF CONDITION FACTORS OF RYŪKYŪ STOCK SCHOOLS (WHITE DOTS) AND OGASAWARA STOCK SCHOOLS (BLACK DOTS). THE HORIZONTAL AXIS SHOWS THE CONDITION FACTOR AND THE VERTICAL AXIS SHOWS THE NUMBER OF FISH.

7. The sources of the skipjack of the Northeastern Sea Area. Looking at the distribution of the positions of catches of migratory and sedentary schools (fig. 7), it can be seen that the sedentary schools are fished in the greatest numbers along the Ogasawara and Zunan archipelagoes, and they are also taken in lesser numbers off Sanriku. In contrast to this, the migratory schools are fished not only in the Zunan and Ogasawara islands, but also in the Southwestern sea area to the west, and, like the migratory schools of the Ryukyu Sea Area, the range of their distribution is not selective. The sedentary schools of the Northeastern Sea Area swim from the Ogasawara chain to the Zunan islands and then migrate on farther to the waters off Sanriku, and therefore they should be called the Ogasawara stock. They are not as bound to islets and shoals as the sedentary schools of the Ryukyu Sea Area. In contrast to these, the migratory schools move into the Northeastern Sea Area from the Ryukyu Sea Area by way of the Southwestern Sea Area, and therefore can be called the Ryukyu stock. It is deduced from the fact that a school of fourth-year fish of the migratory type was fished by the Fusa Maru in the vicinity of Douglas Shoal on May 1, 1936, that migration is not restricted to the routes following the coast of Honshu, but that the fish also migrate through the offshore waters to the south. The migratory fourth-year fish of the Ryukyu Sea Area and the migratory fourth-year fish of the Northeastern Sea Area resemble each other very closely in the trend of change of the average and mode of their body lengths (table 9). What are thought to be facts that enable us to deduce that the schools of fourth-year migratory fish of the Ryukyu Sea Area do migrate away are: (1) The proportion of migratory fourth-year fish in the catch becomes lower as one goes toward the more northern fishing grounds (table 1); (2) In years when migratory schools are plentiful the amount of the catch in the Ryukyu Sea Area diminishes (1935). These phenomena are thought to be ascribable to the fact that fourth-year fish do not remain permanently on the fishing grounds. The skipjack schools that are fished in the Southwestern Sea Area are migratory fourth-year fish, and their age composition and condition factor resemble those of the migratory fourth-year fish of the Ryukyu and Northeastern Sea Areas (table 10). No connection can be found between the sedentary schools of the Northeastern Sea Area, that is, the Ogasawara stock, and the sedentary schools of the Ryukyu Sea Area. Schools of fifth-year fish are scarce in the Ogasawara stock in the Northeastern Sea Area, but it is thought that in the Ogasawara archipelago and farther south fifth-year fish are much more numerous. The skipjack taken by the Fuji Maru in the middle of May, 1935, in the waters adjacent to Marcus I. (153° 59'E, 24° 11'N) were sedentary fifth-year fish with an average body weight of 4.5 kg, body length of 6.3 cm [Sic. Probably 63 cm.], and condition factor of 17-18.

Thus there are two distinct stocks that come into the Northeastern Sea Area. Fluctuations in the catch are probably closely related to the volume of migration of each group. Future investigations should pay considerable attention to this point.

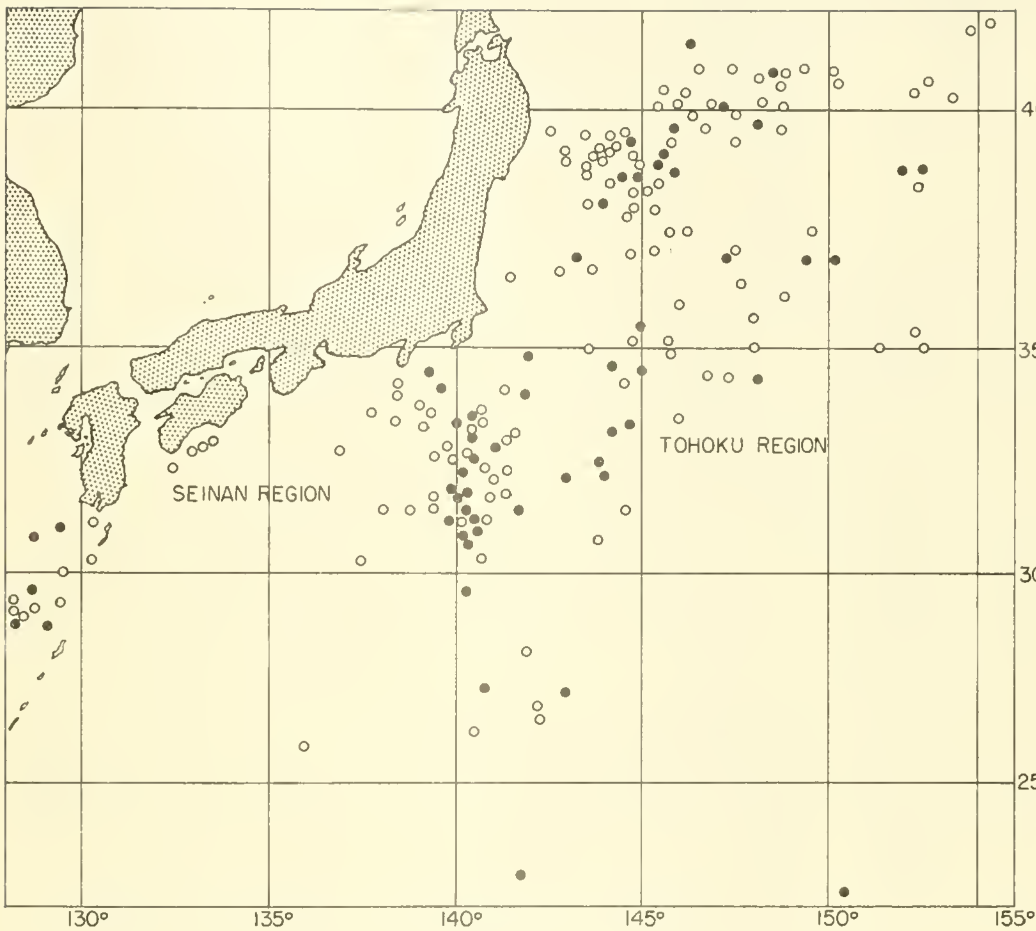

FIG. 7 DISTRIBUTION OF THE POSITIONS OF CATCHES OF RYŪKYŪ STOCK SCHOOLS (WHITE DOTS) AND OGASAWARA STOCK SCHOOLS (BLACK DOTS) (NORTHEASTERN SEA AREA, 1934 - 36)

Table 9. Changes in the body length of fish of both groups in the Ryukyu and Northeastern sea areas

Year	Migratory schools				Sedentary schools			
	Ryukyu		Northeastern		Ryukyu		Northeastern	
	Average	Mode	Average	Mode	Average	Mode	Average	Mode
1934	44.8	44	50.2	50	46.4	46	51.8	56
1935	43.5	41	46.2	45	47.2	45	49.0	53
1936	42.9	41	43.4	42	43.2	46	49.7	41

Table 10. Comparison of the characteristics of schools of migratory fourth-year fish from three sea areas (June 1936)

Length	Ryukyu			Southwestern			Northeastern		
	Fish	w	f	Fish	w	f	Fish	w	f
34				1	1.0	25.9	1	1.5	35.0
35									
36	3	1.0	22.1						
37	6	1.1	22.2	111	1.1	22.4	2	1.8	35.2
38	7	1.2	22.1				5	1.3	24.0
39	4	1.3	21.6				22	1.4	24.0
40	4	1.4	21.8	164	1.4	21.8	11	1.6	25.1
41	19	1.6	24.0	2	1.7	24.7	55	1.5	22.1
42	0	1.7	22.7	1	1.8	24.3	69	1.6	22.2
43	4	1.8	22.6	140	1.9	23.5	88	1.7	22.2
44	6	1.9	22.2	2	2.1	24.6	52	1.8	21.4
45	8	2.0	21.9				50	2.0	22.3
46	7	2.1	21.9	31	2.3	24.0	34	2.2	21.8
47	2	2.5	21.9	2	2.4	23.2	16	2.0	19.9
48	5	2.4	23.1				10	2.5	23.2
49	3	2.6	21.5	9	2.7	22.1	9	2.7	22.9
50	3	2.7	22.1				8	3.1	25.2
51	1	3.0	22.6				8	3.0	22.3
52	1	3.2	22.8				4	3.3	23.2
53	1	3.8	25.5				5	3.6	24.7
Av.	84	1.8	22.4	463	1.6	22.4	449	1.9	22.9
	L 42.9			L 3.06			L 4.36		

(TN. w probably represents weight in kg; f = condition factor. L appears to be the average length of the fish.)

In the averages for 1934-1935 the Ryukyu stock was 80% and the Ogasawara stock was 20%. Accordingly it is thought that the Ryukyu stock plays an important role in the fluctuations of the skipjack catch of the Northeastern Sea Area (table 11). The foregoing represents an attempt to make two or three deductions concerning the age composition, types of schools, and provenance of the skipjack schools on the Pacific coast of Japan, however, there are still many points which require examination and therefore it is thought that future investigations will amplify and correct these hypotheses.

Table 11. Percentage of skipjack schools of each stock fished in the Northeastern Sea Area

Year	Ryukyu stock	Southern stock	Number of fish caught by research vessels (in 100's)	Total number of fish caught (in 1,000's)
1934	60.8%	29.2%	807	7161
1935	87.6	12.4	851	5382
1936	82.5	17.5	3097	6953*
Totals	79.6	20.4	4755	

*This is the catch to the end of June 1936

From the Bulletin of the Japanese Society of Scientific Fisheries, Vol. 3, No. 4, pp. 196-202. November 1934.

Local Variations in the Composition of Skipjack (*Katsuwonus pelamis*) Schools

by

Michitaka Uda and Jirō Tsukushi

(Central Fisheries Experiment Station)

[English title and synopsis]

Local variations in the Composition of Various Shoals of "Katuwo", *Euthynnus vagans* (Lesson), in Several Sea-districts of Japan

Mititaka Uda and Zirō Tukusi

SYNOPSIS

A study of the fisheries of "Katuwo", *Euthynnus vagans* (Lesson), in several sea districts adjacent to Japan in 1933, leads to some interesting results concerning their shoaling conditions -- associated objects such as birds, sharks, whales, drifting timbers or what not; whether they are attached to banks or not; denseness or crowding; degree of biting; index of angling; and the size of individuals, which is classified into large (over 3.75 kg. wt.) [8 lbs.] medium (1.88 to 3.75 kg. wt.) [4 to 8 lbs.], and small (less than 1.88 kg. wt.) [under 4 lbs.], sizes -- in relation to the frequencies of their appearances and the size of catches.

From the study, for each sea-district, of the months, in which the maximum percentage catch of fishes of each size-group, above mentioned, is attained in the fishing season, the following results of discussions on the migration of "Katuwo" will be given: (1) The shoals, consisted mainly of fishes of medium size, migrated in 1933 from the southern to the northern sea-district from spring to summer, accompanied, in consequence, by the movement of their fishing grounds. (2) On the other hand, it can be noticed that the local groups found around the banks in southern sea-districts consisted of comparatively high percentage of fishes of large and small sizes in addition to those of medium size.

The composition of various shoals of "Katuwo" in each sea-district has some respective peculiarity. In the northern sea-district the shoals are mainly associated with sharks or without

anything and crowded densely in number, while in the southern, they are mainly associated with birds or are attached to banks and crowded thinly. The leading shoals varies from northern to southern sea-districts in succession from those associated with sharks, to what not, those associated with whales, birds or drifting timbers and to those attached to banks.

(end of English synopsis)

In the investigation of the fishing situation of migratory fishes like the skipjack and tuna, all sorts of basic studies with regard to the ecology of the schools are thought to be essential[1]. The present paper represents the results of a small investigation based on the latest data concerning the composition of skipjack schools. The data are taken from the reports of the fisheries experiment stations of the various prefectures and metropolitan districts which participated in the Cooperative Skipjack Fishery Investigations for 1933 (Taihoku, Okinawa, Kumamoto, Kagoshima, Wakayama, Mie, Aichi, Kanagawa, Tōkyō, Ibaragi, Fukushima, Miyagi, and Iwate)[2].

<u>Large, medium, and small fish</u>. Here fish with a body weight greater than 8 lbs. are called large, those between 4 and 8 lbs. are called medium, and those under 4 lbs. are called small. The sea areas are divided into the Hokkai-Sanriku Sea Area (north of a line drawn SE from Nojimazaki), Zunan Sea Area (east of a line drawn due south from Omaezaki, and extending to the limits of the Hokkai-Sanriku Sea Area), the Nankaidō Sea Area (east of a line drawn due south from Hisaki to the limits of the Zunan Area), and the Satsunan Sea Area (east of a line joining Nomasaki and Fukikaku to the limits of the Nankaidō Sea Area).

Table 1 shows the numbers and percentages of skipjack of each size taken in each area and in each month, and from it the following can be stated: (1) In the Hokkai-Sanriku Sea Area the number of medium skipjack taken (85 percent of the whole) and the number of their appearances (75 percent of the whole) are overwhelmingly predominant, and they make up the most important element in the composition of the schools in this area.

1/ K. Kishinouye: Contributions to the comparative study of the so-called scombroid fishes. Jour. Coll. Agric. Imp. Univ. Tokyo, 8(3), pp. 293-475 is a valuable contribution in this field.

2/ The detailed data have been omitted from this paper. Consult the reports of operations by the agencies concerned for the year 1933.

Table 1a.--Number and percentages (in parentheses) of appearances of schools of large, medium, and small skipjack in each month in each sea area (1933).

Month	Satsunan			Nankaidō			Zunan			Hokkai-Sanriku		
	Large	Medium	Small	Large	Medium	Small	Large	Medium	Small	Large	Medium	Small
March	1 (17)	3 (50)	2 (33)	-- (--)	-- (--)	-- (--)	-- (--)	-- (--)	-- (--)	-- (--)	-- (--)	-- (--)
April	4 (17)	9 (37)	11 (46)	-- (--)	3 (75)	1 (25)	-- (--)	12 (80)	3 (20)	-- (--)	-- (--)	-- (--)
May	17 (38)	3 (7)	24 (55)	-- (--)	-- (--)	3 (100)	1 (10)	5 (45)	5 (45)	1 (2)	34 (76)	10 (22)
June	8 (31)	2 (8)	16 (61)	-- (--)	-- (--)	-- (--)	3 (18)	7 (44)	6 (38)	4 (7)	44 (77)	9 (16)
July	9 (35)	1 (4)	16 (61)	-- (--)	-- (--)	-- (--)	5 (18)	13 (46)	10 (36)	9 (11)	61 (79)	8 (10)
August	6 (44)	3 (21)	5 (35)	-- (--)	-- (--)	-- (--)	-- (--)	5 (63)	3 (37)	5 (14)	26 (75)	4 (11)
September	4 (31)	9 (69)	-- (0)	-- (--)	-- (--)	-- (--)	-- (--)	2 (67)	1 (33)	5 (18)	17 (61)	6 (21)
October	1 (25)	1 (25)	2 (50)	-- (--)	-- (--)	-- (--)	-- (--)	1 (50)	1 (50)	-- (--)	-- (--)	-- (--)
Totals	50 (32)	31 (19)	76 (49)	-- (--)	3 (43)	4 (57)	9 (11)	45 (54)	29 (35)	24 (10)	185 (75)	37 (15)

Table 1b.--Numbers and percentages (in parentheses) of fish taken from schools of large, medium, and small skipjack in each month in each sea area.

Month	Satsunan			Nankaidō			Zunan			Hokkai-Sanriku		
	Large	Medium	Small	Large	Medium	Small	Large	Medium	Small	Large	Medium	Small
March	575 (33)	1,050 (61)	95 (6)	-- (--)	-- (--)	-- (--)	-- (--)	-- (--)	-- (--)	-- (--)	-- (--)	-- (--)
April	1,137 (18)	651 (11)	4,400 (71)	0 (0)	1,502 (89)	185 (11)	-- (--)	4,373 (88)	570 (12)	-- (--)	-- (--)	-- (--)
May	5,062 (25)	372 (2)	14,805 (73)	0 (0)	0 (0)	625 (100)	65 (3)	964 (45)	1,100 (52)	50 (0)	42,789 (89)	5,200 (11)
June	1,075 (12)	14 (0)	7,845 (88)	-- (--)	-- (--)	-- (--)	103 (1)	4,210 (35)	7,518 (64)	5,540 (11)	36,747 (77)	5,721 (12)
July	3,603 (38)	317 (3)	5,651 (59)	-- (--)	-- (--)	-- (--)	334 (2)	7,763 (35)	14,138 (63)	9,394 (7)	124,652 (91)	2,773 (2)
August	1,412 (46)	360 (11)	1,308 (43)	-- (--)	-- (--)	-- (--)	0 (0)	1,050 (81)	241 (19)	5,529 (13)	31,428 (78)	3,560 (9)
September	1,044 (11)	8,903 (89)	-- (0)	-- (--)	-- (--)	-- (--)	0 (0)	285 (76)	90 (24)	1,785 (7)	17,487 (75)	4,439 (18)
October	62 (7)	21 (3)	754 (90)	-- (--)	-- (--)	-- (--)	0 (0)	603 (51)	590 (49)	-- (--)	-- (--)	-- (--)
Totals	13,973 (23)	11,688 (19)	34,858 (58)	-- (0)	1,502 (65)	810 (35)	552 (1)	19,248 (44)	24,247 (55)	22,298 (8)	253,103 (85)	21,693 (7)

(2) Schools of medium skipjack occur in a higher ratio as one goes toward the more northern areas and in a lower ratio as one goes toward the sea areas to the north and west of Japan. (In the Zunan Sea Area they make up 44 percent of the total catch and 54 percent of the total frequency, while in the Satsunan Sea Area they account for about 20 percent of total catch and total frequency). The schools of large and small skipjack, on the other hand, decrease both absolutely in numbers and frequency and in their percentages as one goes farther north, but in the southern and southwestern sea areas they show comparatively high ratios. (3) The number of fish and the number of appearances for medium skipjack as compared to large and small skipjack show their maximum proportions in the Hokkai-Sanriku Sea Area during the summer months of May - August, which corresponds to the time when their proportions are at their minimum in the southwestern sea areas. (4) In September the number of medium skipjack in proportion to large and small skipjack in the Hokkai-Sanriku Sea Area suddenly decreases, while on the other hand, it shows a relatively high ratio in the (Zunan) Satsunan Sea Area3/. (5) In the Satsunan Sea Area the total catch is highest in May, and it is then that the large and small fish, which make up 80 percent of the total number of fish caught, are taken in the greatest numbers, while the other 20 percent of medium fish are most numerous in September and March, that is, at the beginning and end of the season. The situation in the Nankaidō Sea Area cannot be clearly known because of the paucity of data, but some catches are made in April and May, and in them medium and small skipjack are taken in about the same proportions. In the Zunan Sea Area, on the whole, June and July are the peak of the fishing season, with July in particular giving the year's maximum catches of all three sizes -- large, medium, and small. The proportions of medium and small fish are roughly the same, but in point of numbers the small fish are more than 10 percent more numerous. In the Hokkai-Sanriku Sea Area the catch reaches its maximum in July, and as much as 91 percent is made up of medium skipjack. If the average catch for each fishing ground is stated in terms of sizes of fish, the order is small, medium, large for the Satsunan and Zunan sea areas, while for the Hokkai-Sanriku Sea Area it is medium, large, small, clearly showing that small skipjack are scarce in the north and abundant in the south.

Next if we investigate the percentages of the numbers of fish caught and the number of catches made in each sea area in each month throughout the whole fishing season in terms of

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3/ Michitaka Uda: Seasonal changes in the body weights of yellowtail, small yellowfin, cybiids, and skipjack. Bull. Jap. Soc. Sci. Fish. 1 (3), p. 128 1932.

Table 2.--Percentages of numbers of large, medium, and small skipjack in the catch for each month during the whole season (percentages of times caught in parentheses)

Month	Satsunan			Nankaidō			Zunan			Hokkai-Sanriku		
	Large	Medium	Small	Large	Medium	Small	Large	Medium	Small	Large	Medium	Small
March	4 (2)	9 (10)	0 (3)	-- (--)	-- (--)	-- (--)	-- (--)	-- (--)	-- (--)	-- (--)	-- (--)	-- (--)
April	8 (8)	6 (29)	13 (14)	-- (--)	100 (100)	23 (25)	-- (--)	23 (27)	2 (10)	-- (--)	-- (--)	-- (--)
May	36 (34)	3 (10)	43 (32)	-- (--)	-- (--)	77 (75)	12 (11)	5 (11)	5 (18)	0 (4)	17 (19)	24 (27)
June	8 (16)	0 (6)	22 (21)	-- (--)	-- (--)	-- (--)	[illegible] (33)	22 (16)	31 (21)	25 (17)	15 (25)	26 (25)
July	26 (18)	3 (3)	16 (21)	-- (--)	-- (--)	-- (--)	70 (56)	40 (29)	58 (35)	42 (37)	49 (33)	13 (21)
August	10 (12)	3 (10)	4 (6)	-- (--)	-- (--)	-- (--)	-- (--)	5 (11)	1 (10)	25 (21)	12 (14)	16 (11)
September	7 (8)	76 (29)	0 (0)	-- (--)	-- (--)	-- (--)	-- (--)	2 (4)	0 (3)	8 (21)	7 (9)	20 (16)
October	0 (2)	0 (3)	2 (3)	-- (--)	-- (--)	-- (--)	-- (--)	3 (2)	2 (2)	-- (--)	-- (--)	-- (--)
Totals	171 (100)	100 (100)	100 (100)	-- (--)	100 (100)	100 (100)	101 (100)	100 (100)	104 (100)	100 (100)	100 (100)	99 (100)

small, medium, and large fish, we get table 2. Table 3 shows the months of maximum catch for each sea area for each size of fish, taken from the data given in table 2. A few observations based on these two tables concerning the skipjack's migrations are presented below. Small skipjack appear in the Satsunan and Nankaido sea areas in April and reach their maximum abundance in May, but in the Zunan Sea Area the peak is in June and July. In the Hokkai-Sanriku Sea Area the somewhat obscure second maximum which can be seen in September may perhaps be thought to be due to the northward movement of schools of small skipjack of the same strain. However, in order to explain the appearance of the first peak in May - June in the Hokkai-Sanriku Sea Area, it is probably necessary to imagine the northward movement of a second group of small skipjack whose origin centers around the Zunan islands and reefs at roughly the same time that the small skipjack of the Satsunan area appear. Next, with regard to the medium-sized skipjack, it is thought that the schools which originate in the Satsunan Sea Area around March and April shift the center of their group of schools to the Nankaidō Sea Area in April and to the Zunan and Hokkai-Sanriku sea areas around July. Another peak in September in the Satsunan Sea Area is thought to be due to the reappearance of downbound skipjack from the Hokkai-Sanriku Sea Area. Furthermore, it may be wondered whether the peak which can be seen, though somewhat obscurely, in April and May in the Zunan and Hokkai-Sanriku sea areas may not be due to a second group of medium skipjack originating in the Zunan Sea Area and moving north from there. As for the large skipjack, the first maximum is the Satsunan Sea Area in May. That moves north to the Zunan Sea Area in July and is thought to form the peak which shows in the Hokkai-Sanriku Sea Area in July and August, but a second peak in the Satsunan Sea Area in May suggests a second origin of schools of large skipjack in this sea area. Of course, it is presumed that the number of small skipjack which grow into medium skipjack, and the number of medium skipjack that grow into large skipjack during the migration must be great, and this must be particularly taken into consideration in waters where the supply of natural foods is abundant, but because of the paucity of data with regard to this point, it has been omitted from the foregoing discussion. The point that should be noted in the migration theory propounded above is that it envisions two strains for large, medium, and small skipjack alike, one originating in the Satsunan Sea Area, and the other in the Zunan Sea Area. Of course, it has been taken into consideration that the schools of skipjack that move north to the Hokkai-Sanriku Sea Area in the summer retreat southward again in the fall. It is probably correct to consider that in the Hokkai-Sanriku Sea Area there is no year-round occurrence of skipjack but a seasonal migration, because the high temperature water masses of 20° C. and above that are present on the fishing grounds off Sanriku in the summer change

Table 3.--Months of maximum catch (percentages of fish caught and of number of times fished).

Size	Area							
	Satsunan		Nankaidō		Zunan		Hokkai-Sanriku	
	Number of fish	Number of times	Number of fish	Number of times	Number of fish	Number of times	Number of fish	Number of times
Small	May	May	May	May	June-July	July	May-June (Sept.)	May-June, (Sept.)
Medium	(March)	April, Sept.	April	April	(April), July	April, July	(May), July	July
Large	May, (July)	May, (July)	--	January	(May) July	July	July	July-August

to low-temperature areas[4] of less than 5° C. in the winter and it is presumed that warm-water fishes such as the skipjack would find it difficult to endure such violent oceanographic changes, which are thought to be specially unsuitable for their spawning and for the growth of the larval fish; also because actually the fish catch ceases in the winter and no fish are seen (it happens rarely that one is hooked on tuna longlines during the winter in warm-water masses far off to the east); and because the catch of large and small fish is markedly smaller than that of medium fish. However, in the Satsunan and Zunan sea areas throughout the whole fishing season some schools of medium-sized skipjack are fished along with the schools of large and small fish that concentrate in the vicinity of islands and reefs and for this reason we know of the existence of other schools which are comparatively sedentary and make only small migrations in addition to the north-south migrating schools described above.

The foregoing discussion is based on only the data for one year so there are many points which require much further study and examination in the future. Particularly the distribution of large, medium, and small sizes, various degrees of maturity, and various degrees of fatness and leanness must be investigated in detail, and the actual paths of the migratory movements of the schools must be ascertained by tagging as many skipjack as possible.

Skipjack schools and the objects with which they are associated. A study like the one previously reported[5] was carried out in 1933 throughout the whole fishing season and over the whole fishing area. Table 4 shows the number of appearances of each type of school and the number of fish caught in each month. In the Hokkai-Sanriku sea area the greatest number of appearances is that for unaccompanied schools followed by schools associated with sharks, birds, whales, and logs in that order. For the total number of fish taken the order was shark-associated, unassociated, whale-associated, bird-associated, and driftwood-associated. Combining the two categories we find that shark-associated and unassociated schools are far more numerous than the other types. In contrast to this, in the Zunan Sea Area there are chiefly bird-associated and sedentary schools, followed by unassociated schools, the extremely small number remaining being driftwood-associated and shark-associated in that order. In the Satsunan Sea Area bird-associated schools are by far the most numerous followed by sedentary and

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4/ Michitaka Uda: Sea conditions in the waters adjacent to Japan in each month averaged over a number of years. Fisheries Experiment Station Reports Nos. 1, 2, 3.

5/ Michitaka Uda: The shoals of "katuwo" and their angling. Bull. Jap. Soc. Sci. Fish. 2 (3), 1933. (See p. 68).

driftwood-associated schools, with a small remainder being shark-associated. The number of fish taken for each school sighted (table 4) in the Hokkai-Sanriku Sea Area is greatest for shark-associated schools followed by driftwood-and whale-associated schools. In the Zunan Sea Area the catch is greatest from bird-associated, sedentary, and unassociated schools; likewise in the Satsunan Sea Area the biggest catches come from bird-associated and driftwood-associated schools, followed by those associated with sharks. If, in order to see in greater detail the difference between northern and southern grounds, we look at the total number and percentages of appearances for each 1° of latitude, as shown in table 5, we see that shark-associated schools are located farthest north with unassociated, whale-associated, bird-associated (driftwood-associated), and sedentary schools ranging in that order from north to south.5/ This distribution results from the fact that the objects with which the schools are associated differ among themselves in their distribution because of oceanographic conditions, and it is thought that as the skipjack schools move into the various sea areas they successively associate themselves with different objects.

Table 6 gives the results of an investigation of the density of the schools and how well the fish bite6/. In the Hokkai-Sanriku Sea Area all types of schools except those associated with birds appear more often as "dense" than as "sparse." On the other hand, in the Zunan and Satsunan sea areas the number of sparse schools appearing was greater for all types. In other words, in the Hokkai-Sanriku Sea Area the proportion of dense schools was markedly greater than in other areas, and consequently the index of density calculated from it is also higher. With regard to biting qualities, it appears that in the Zunan and Satsunan sea areas sedentary and bird-associated schools bite comparatively well, while in the Hokkai-Sanriku sea area shark-and bird-associated schools bite comparatively well. The problem of the density of schools and their biting qualities has many points which must be clarified by future investigations. Since it appears that the spawning and nursery grounds of the skipjack are in the southern areas, it may be wondered whether the migration into the Hokkai-Sanriku Sea Area is not made with the objective of hunting food. The greater number of times that the schools take the bait poorly as compared to the Satsunan Sea Area, despite the greater proportion of dense schools, may possibly be due to the abundance of natural food in the north. The greater number of dense schools in this sea area is probably due to special oceanographic conditions in that there are conspicuous current boundaries resulting from water of the cold current system barring the advance of the water of the warm current system.

6/ The order of the indices of density and biting shown in table 6 differs from that given in reference5/. In the present study the statistics covered a larger number of schools, however, decision on this point is reserved to the future.

Table 4a.--Number of appearances of various types of skipjack schools, number of fish taken, and number of fish taken per time fished in the Hokkai-Sanriku Sea Area.

Number of appearances of schools of each type

Month	Objects with which associated				
	Shark	Nothing	Whale	Bird	Driftwood
March	--	--	--	--	--
April	--	--	--	--	--
May	2	11	9	16	--
June	3	24	10	19	--
July	30	25	9	2	2
August	14	18	--	--	--
September	9	9	1	1	--
October	--	--	--	--	--
Totals	58	87	29	38	2

Number of fish taken from schools of each type

Month	Objects with which associated				
	Shark	Nothing	Whale	Bird	Driftwood
March	--	--	--	--	--
April	--	--	--	--	--
May	10,607	14,764	10,571	7,292	--
June	3,734	14,201	15,222	8,013	--
July	70,325	44,452	12,860	150	3,025
August	15,441	24,551	--	--	--
September	14,190	7,707	1,000	544	--
October	--	--	--	--	--
Totals	114,297	105,675	39,653	15,999	3,025

Number of fish taken per time fished from each type of school

Month	Objects with which associated				
	Shark	Nothing	Whale	Bird	Driftwood
March	--	--	--	--	--
April	--	--	--	--	--
May	5,304	1,342	1,175	456	--
June	1,267	592	1,522	422	--
July	2,944	1,778	1,429	75	1,513
August	1,103	1,364	--	--	--
September	1,577	856	1,000	544	--
October	--	--	--	--	--
Averages	1,973	1,215	1,366	421	1,513

Table 4b.—Number of appearances of various types of skipjack schools, number of fish taken, and number of fish taken per time fished in the Zunan Sea Area

Number of appearances of schools of each type

Month	Objects with which associated				
	Shark	Nothing	Bird	Land	Driftwood
March	—	—	—	—	—
April	—	12	10	—	—
May	1	4	—	—	1
June	—	1	5	5	—
July	—	—	14	13	—
August	—	—	3	7	—
September	—	—	2	2	—
October	—	—	3	—	—
Totals	1	17	37	27	1

Number of fish taken from schools of each type

Month	Objects with which associated				
	Shark	Nothing	Bird	Land	Driftwood
March	—	—	—	—	—
April	—	4,474	1,316	—	—
May	65	715	—	—	494
June	—	4,030	6,029	1,681	—
July	—	—	9,982	12,333	—
August	—	—	669	595	—
September	—	—	188	187	—
October	—	—	1,793	—	—
Totals	65	9,219	19,977	14,796	494

Number of fish taken per time fished from each type of school

Month	Objects with which associated				
	Shark	Nothing	Bird	Land	Driftwood
March	—	—	—	—	—
April	—	373	132	—	—
May	65	179	—	—	494
June	—	4,030	1,206	356	—
July	—	—	713	949	—
August	—	—	223	85	—
September	—	—	94	94	—
October	—	—	597	—	—
Averages	65	542	540	548	494

Table 4c.—Number of appearances of various types of skipjack schools, number of fish taken, and number of fish taken per time fished in the Satsunan Sea Area.

Number of appearances of schools of each type

Month	Objects with which associated			
	Shark	Bird	Land	Driftwood
March	—	4	—	—
April	—	1	2	—
May	1	8	2	—
June	—	—	3	1
July	—	4	4	—
August	—	4	—	—
September	—	—	—	—
October	—	1	—	1
Totals	1	22	11	2

Number of fish taken from schools of each type

Month	Objects with which associated			
	Shark	Bird	Land	Driftwood
March	—	813	—	—
April	—	364	1,184	—
May	462	5,827	477	—
June	—	—	482	320
July	—	2,656	715	—
August	—	2,692	—	—
September	—	—	—	—
October	—	62	—	745
Totals	462	12,314	2,858	1,065

Number of fish taken per time fished from each type of school

Month	Objects with which associated			
	Shark	Bird	Land	Driftwood
March	—	203	—	—
April	—	364	592	—
May	462	728	238	—
June	—	—	131	320
July	—	664	179	—
August	—	673	—	—
September	—	—	—	—
October	—	62	—	745
Averages	462	559	259	523

Table 5.--Numbers and percentages of various types of skipjack schools appearing in each 1° of latitude in the Hokkai-Sanriku and Zunan sea areas (1933)

Latitude	Number of appearances of schools by types							Percentages of appearances by each type					
	Shark	Plain	Whale	Birds	Sedentary	Driftwood	Total	Shark	Plain	Whale	Birds	Sedentary	Driftwood
41° - 42°N	8	6	1	--	--	--	15	53	40	7	0	0	--
40 - 41	7	16	--	--	--	--	23	30	70	0	0	0	0
39 - 40	11	8	4	2	--	--	25	44	32	16	8	0	0
38 - 39	5	8	2	2	--	1	18	28	44	11	11	0	6
37 - 38	4	8	--	--	--	1	13	31	61	0	0	0	8
36 - 37	8	8	--	3	--	--	19	42	42	0	16	0	0
35 - 36	10	15	12	15	--	--	52	19	29	23	29	0	0
34 - 35	3	8	4	5	--	--	20	15	40	20	25	0	0
33 - 34	1	5(3)	3	9(4)	--	(1)	19	5	26	16	48	0	5
32 - 33	2(1)	18(17)	3	12(6)	--	--	35	7	51	8	34	0	0
31 - 32	--	1	--	--	--	--	1	0	100	0	0	0	0
30 - 31	--	--	--	1	1	--	2	0	0	0	50	50	0
29 - 30	--	--	--	8	5	--	13	0	0	0	61	39	0
28 - 29	--	--	--	--	--	--	--	--	--	--	--	--	--
27 - 28	--	--	--	7	3	--	10	0	0	0	70	30	0
26 - 27	--	1	--	6	9	--	16	0	7	0	37	56	0
25 - 26	--	--	--	5	7	--	12	0	0	0	42	58	0
24 - 25	--	--	--	--	--	--	--	--	--	--	--	--	--
23 - 24	--	--	--	--	--	--	--	--	--	--	--	--	--
22 - 23	--	1	--	--	--	--	1	0	100	0	0	0	0
21 - 22	--	--	--	--	--	--	--	--	--	--	--	--	--
20 - 21	--	--	--	--	--	--	--	--	--	--	--	--	--
19 - 20	--	--	--	--	1	--	1	0	0	0	0	100	0
18 - 19	--	--	--	--	1	--	1	0	0	0	0	100	0

Figures in parentheses show data from south of the Zunan Sea Area (34° N).

Table 6.--Density and biting qualities of different types of skipjack schools (1933)

Sea area and type of school	Density (number of schools)			Biting qualities (number of schools)			
	Dense	Sparse	Index	Good	Average	Poor	Index
Hokkai-Sanriku Sea Area							
shark	34	16	0.71	18	7	30	1.27
plain	44	38	0.58	25	11	50	1.17
whale	16	11	0.63	8	2	19	1.09
birds	13	22	0.43	5	2	8	1.29
driftwood	2	--	1.0	1	--	--	--
sedentary	--	--	--	--	--	--	--
Zunan Sea Area							
shark	--	1	(0.1)	--	--	1	(0.1)
plain	2	15	0.21	2	3	12	0.74
whale	--	--	--	--	--	--	--
birds	[illegible]	29	0.30	8	--	27	0.92
driftwood	1	--	(1.0)	--	--	--	--
sedentary	9	18	0.40	--	--	--	--
Satsunan Sea Area							
shark	--	1	(0.1)	1	--	--	(3.0)
plain	--	--	--	--	--	--	--
whale	--	--	--	--	--	--	--
birds	6	16	0.35	13	--	9	2.0
driftwood	4	6	0.46	--	--	--	--
sedentary	--	2	(0.1)	--	--	--	--

Notes: 1. In calculating the index of density the standard indices were taken to be 1 for dense schools and 0.1 for sparse schools.

2. The figures in parentheses in the table are data which are unreliable because of the paucity of examples.

3. In calculating the index of biting the standard indices were taken to be 3 for "good", 1 for "average", and 0.3 for "poor".

Conclusion

From the 1933 investigations it appears that the skipjack schools of the Hokkai-Sanriku Sea Area have characteristics differing from those of the southern sea areas as regards the size of the fish and the objects with which they are associated, and further that the water temperatures suitable for catching them are markedly lower than in the south and have comparatively limited values ($22-23^{\circ}$ C)7/, all of which seems to mark it off as an area in which the schools are clearly of a different composition, however, it is thought that the schools themselves come from the Zunan Sea Area and the areas to the south and west (including Satsunan) in the spring and summer and return south in the fall.

Finally I wish to thank Dr. Morisaburō Tauchi, professor in the Fisheries Institute, for his valuable instruction concerning the theory of skipjack migrations presented in this paper, and Technician Itarō Takayama of the Imperial Fisheries Experiment Station for making the data available.

Summary

(1) According to the investigations of 1933, the majority of the skipjack schools fished in the Hokkai-Sanriku Sea Area are medium-sized skipjack, while in the southern sea areas schools of large and small fish make up a comparatively important part of the catch. The proportion of medium skipjack to large and small fish is least in the southern areas at the same period (May, June, July) when it is greatest in the Hokkai-Sanriku Sea Area.

(2) Investigating the month of highest catch in each sea area by large, medium, and small sizes, the migrations of the skipjack schools were discussed separately by sizes. Groups of skipjack schools which migrate from south to north in the spring and summer and retreat southward again in the fall were hypothesized and it was thought that they must be composed of schools of at least two strains, one originating in the Satsunan area and one in the Zunan area. Further, it is thought that there are probably only migratory schools, with no permanently resident schools, in the Hokkai-Sanriku Sea Area, but for the Zunan and Satsunan sea areas we must believe that there are, in addition to the north-south migrating schools, other local schools which make small localized migrations.

7/ Takayama, Ikeda, and Andō: A study of the skipjack fishing situation in 1930. Jour. Imp. Fish. Expt. Sta. No. 5, 1934, 33-34.

(3) In the Hokkai-Sanriku Sea Area the skipjack schools are mainly associated with sharks or not associated with anything, and both the number of dense schools and the index of density are remarkably high, but in the Zunan and Satsunan sea areas they are chiefly bird-associated or sedentary schools, and sparse schools are more numerous than dense ones. A look at the distribution shows that the shark-associated schools occur the farthest north followed by unassociated, whale-associated, bird-(driftwood-) associated, and sedentary schools in that order. The results of a certain amount of investigation of the biting qualities of schools as well as their density and associations have also been presented.

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Types of Skipjack Schools and Their Fishing Qualities

By

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[English title and abstract]

The Shoals of "Katuwo" and their Angling.

SYNOPSIS

The shoal of "Katuwo" [Euthynnus vagans (Lesson)] is often found associated with either sea-birds, drifting timbers, whales, sharks, or what not. The association with sea-birds or whales is almost characteristic to the shoals of this fish found in the districts south to Prov. Bosyu, whereas the shoals associated with sharks are mostly distributed in the northern districts. Such difference of the distribution corresponds to that of oceanographical conditions, particularly of salinity (Figs. 1, 2 and Tab. 1).

The denseness of crowd and the degree of biting are represented quantitatively with the index-numbers k and q respectively (Tabs. 2 and 3), viz., $k = \frac{m + 0.1n}{m + n}$, where m and n are the number of records of dense and thin crowds respectively, and

$$q = \frac{3p_2 + 2p_1 + p_0 + 0.5p_{-1} + 0.1p_{-2}}{p_2 + p_1 + p_0 + p_{-1} + p_{-2}},$$

where p_2, p_1, p_0, p_{-1} and p_{-2} are the number of records of very good, good, medium, poor and very poor biting respectively. The index-number of fishing value of a shoal defined by $\frac{N'}{lt}$, where N', l and t are the total number of fishes angles, the number of rods used and the duration of angling respectively, varies with the product kq (Tab. 6). But, since N' is not exactly proportional to t (Tab. 5), the above-mentioned index number is only an approximate one.

The relation between the degree of biting of "Katuwo" and the quantity of the contents of their stomach (Tab. 4) seems to be explained by taking the time required for digestion into account.

[End of English abstract]

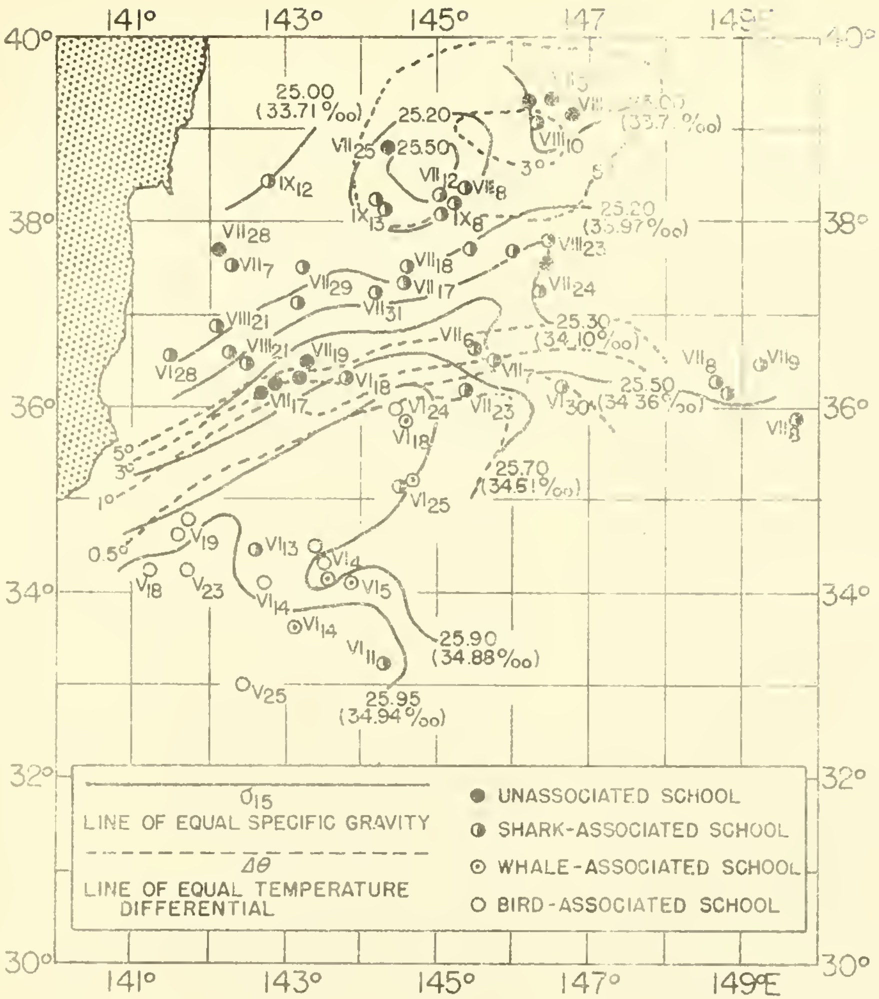

FIG. 1 σ_{15}; TEMPERATURE DIFFERENTIAL BETWEEN 0M AND 25M; AND DISTRIBUTION OF THE VARIOUS TYPES OF SCHOOLS ON THE SKIPJACK FISHING GROUNDS (FROM THE SURVEY BY THE HANJŌ MARU) THE FIGURES ON THE CHART ARE THE DATE OF THE CATCH.

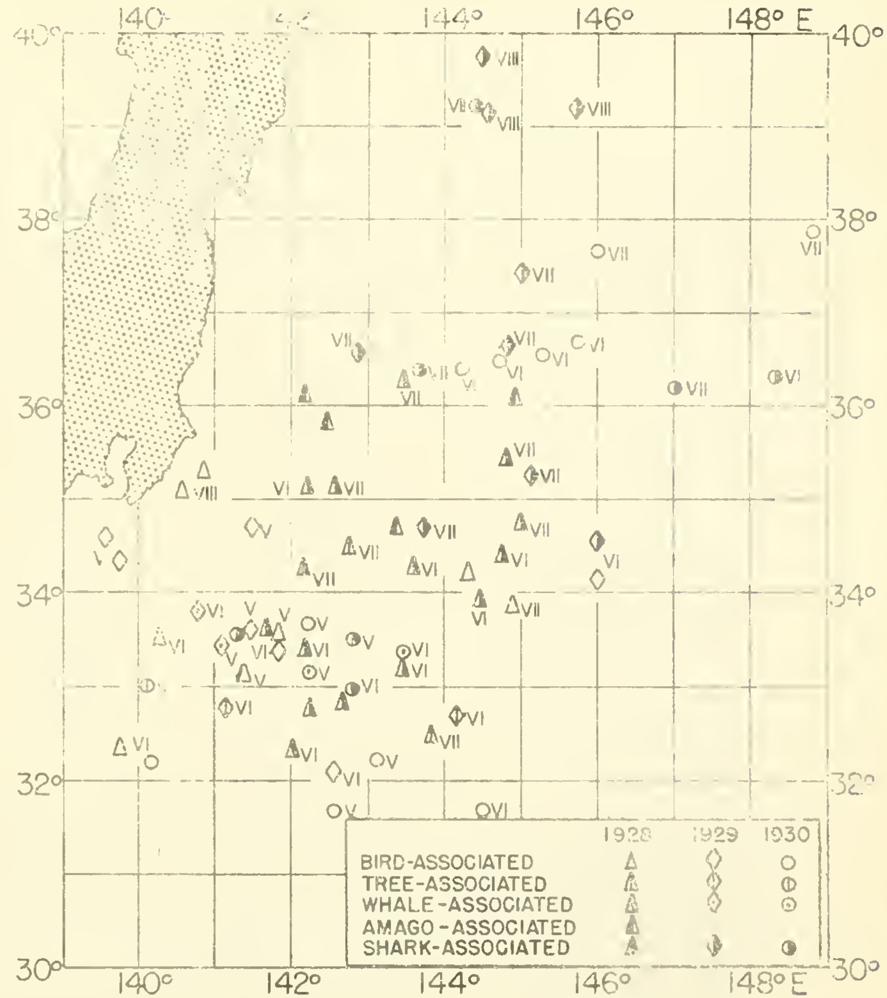

FIG. 2 DISTRIBUTION OF SKIPJACK SCHOOLS (FROM INVESTIGATIONS BY THE CHIBA PREFECTURE FISHERIES EXPERIMENT STATION). THE FIGURES ON THE CHART ARE THE MONTH IN WHICH THE CATCH WAS MADE.

This paper is a result of some studies which I have made of the ecology of skipjack schools, using records made on the skipjack fishing grounds by the Hanjō Maru of the Fukushima Prefecture Fisheries Experiment Station. In classifying types of skipjack schools, I have followed the procedure of the Fukushima Prefecture Fisheries Experiment Station[1] and of Mr. Shin Suzuki[2].

Types of Schools and Sea Conditions.

A comparison of the distribution of fishing grounds and the distribution of salinities (table 1) shows that in May and June southeast of the province of Bōshū [Chiba Prefecture], in a warm current area of high salinity ($\sigma_{15} > 25.70$) the main types of schools encountered are those associated with whales or with flocks of birds, while in July, August, and September, in the waters of comparatively low salinity to the north ($\sigma_{15} < 25.70$), the only schools seen are those associated with sharks or those not associated with anything. Surface water temperatures on the fishing grounds are everywhere roughly the same (21° to 23° C.), but the differential in temperature between the surface and the 25-meter level shows approximately the same distribution as the salinity, both of them being thought to indicate a difference in current system (fig. 1). Of course the fishing season in the south is in May and June, while in the north it is in July, August, and September. It may be thought that this is the reason for the greater vertical difference in water temperature in the north, however, in this sea area, the regular yearly studies also reveal a greater vertical difference in temperature the farther north one goes.[2] This relationship between current systems and types of skipjack schools can be seen from the records of investigations carried out by the Chiba Prefecture Fisheries Experiment Station over a period of three years (fig. 2)[2].

Taking the waters off Bōshū as a boundary, it is not clear why there is a difference in the types of skipjack schools found to the north and to the south. It may be wondered whether this difference is not due to differences in the distribution of the objects with which the schools are associated, this distribution being affected by oceanographic conditions[3], rather than to differences in the character of the skipjack schools themselves. Suzuki[2] defines the unaccompanied schools as those which appear at the surface in areas where there are no other objects or signs of life, and bird schools as those which cannot be detected except by sighting flocks of sea birds. The sharks are whale sharks, around which the skipjack

Table 1.--Frequency of appearance of types of skipjack schools

Month	> 25.90	25.70 25.89	25.50 25.69	25.30 25.49	25.00 25.29	25.00 >	bird	whale	shark	unaccom-panied
	← 15									
V	bird 5	--	--	--	--	--	5	--	--	--
VI	bird 2 whale 3 shark 2	bird 1 whale 1 shark 1	shark 1	--	--	--	4	5	5	--
VII	--	--	shark 2 unacc.4	shark 1 unacc.1	shark 3	--	--	--	10	6
VIII	--	--	shark 2	shark 2	shark 5 unacc.1	shark 1 unacc.1	--	--	11	3
IX	--	--	--	shark 1	shark 4 unacc.2	--	--	--	6	2
Total times	12	3	9	5	15	2	9	5	32	11
Bird	7(58%)	1(33%)	--	--	--	--				
Whale	3(25%)	1(33%)	--	--	--	--				
Shark	2(17%)	1(33%)	5(56%)	4(80%)	12(80%)	1(50%)				
Unaccom-panied	--	--	4(44%)	1(20%)	3(20%)	1(50%)				

Note: The frequencies in the columns above include cases for which specific gravity observations are lacking.

schools congregate in fear of spearfish. Among whales accompanied by skipjack schools, the sei whale is most common followed by the fin whale. Floating logs are mainly of tropical origin, having picked up their accompanying schools while drifting past the shoal fishing grounds. Consequently, according to Suzuki, such schools accompanying drift logs are sighted in greatest numbers in the main current of the Kuroshio between the Satsunan fishing grounds and Zunan, such schools being rare within 200 miles of the coast, north of Tokiwa.*

Thus, skipjack schools associated with birds, with whales, or with floating logs generally appear in greatest numbers in waters of the main Kuroshio system, while schools accompanying sharks appear for the most part in warm water masses of the Northeastern Sea Area where the Kuroshio and Oyashio current systems impinge upon each other. Schools accompanying whales are said to be hard to find in the southern portion of the Kuroshio. Consequently, the distribution of salinity and distribution of types of skipjack schools are probably correlated.

Index to the Density of Schools.

As the schools associate with birds, trees, whales, or sharks for quite different reasons - quite fortuitously in the case of the birds, in search of rich feed in the case of drift logs, and to escape predators in the case of whales and sharks - and the objects with which the schools are associated differ in their size and rate of movement, it may be thought natural that differences in density and size should also arise among these various types of schools. The following is an attempt to express the degree of density numerically. Fist of all, for each type of school the number of times of appearance of dense schools is indicated by m, the number of times of appearance of sparse schools by n, the concentration in space of individual fish in the case of dense schools is represented by the density index 1, and in the case of sparse schools by x (1 x 0). Therefore, the index of average density of a school of fish is

$$k = \frac{m X 1 - n X x}{m - n}.$$

By means of this formula k is calculated using observed values for m and n and postulating two values 0 and 0.1 for x (table 2). In the case of unaccompanied schools k is 1, for schools accompanying whales and sharks it is about 0.8, for schools accompanying birds it is 0.1 or 0.2.

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* Nakayama5/ also expresses generally the same idea.

Table 2.--Density and density indices for skipjack schools

Type of School	Times recorded		Density index (k)	
	Dense (m)	Sparse (n)	x = 0.1	x = 0
Bird	1	8	0.2	0.11
Whale	4	1	0.82	0.80
Shark	24	8	0.78	0.75
Unaccompanied	11	0	1.0	1.0

Table 3.--Biting qualities and biting quality indices for skipjack schools

Type of school	Times recorded					Biting index (q)
	Good p_2	Fairly good p_1	Average p_0	Poor p_{-1}	Very poor p_{-2}	
Bird	-	3	-	6	-	1.00
Whale	2	2	-	1	-	2.10
Shark	2	2	2	25	1	0.77
Unaccompanied	3	1	-	7	-	1.32

Table 4.--Stomach contents and biting qualities

Stomach contents		Frequency			
Type	Amount	Good	Fairly good	Average	Poor
Sea-trout	full	3			4
Chirocentrids	fairly full	1	1		2
Chirocentrids	stuffed		3		
Chirocentrids and sea-trout	some				1
Spratelloides sp.	half full				1
Chirocentrids and others	a little		1	1	2
Chirocentrids	a little				2
Nothing	nothing	1			1
Not recorded		2	2	1	27

(Note) Bait used was sardine or anchovy

Index to Biting Qualities of Schools.

The following is an attempt to show numerically the biting qualities of skipjack schools. If the biting qualities of a school recorded as good, fairly good, average, poor, and very poor, are indicated respectively by y_2, y_1, y_0, y_{-1}, and y_{-2}, and the number of times of occurrence for each category is expressed as p_2, p_1, p_0, p_{-1} and p_{-2}, the index of average biting qualities for one type of school can be shown by the formula $q = \frac{\Sigma\ py}{\Sigma\ p}$. Now when $y_2 = 3$, $y_1 = 2$, $y_0 = 1$, $y_{-1} = 0.5$, and $y_{-2} = 0.1$, if we try calculating q (table 3), we get 2.1 for schools accompanying whales, 1.3 for unaccompanied schools, 1.0 for schools accompanied by birds, and 0.8 for schools accompanying sharks. An unexpected relationship can be seen between the biting qualities of schools and the stomach contents of the fish (table 4). Fish which have eaten their fill and fish with empty stomachs may either bite well or poorly, but fish between these two extremes tend to bite more poorly the less they have in their stomachs. It is thought that once the fish has filled its stomach, its appetite declines with the progress of digestion, the appetite becoming strong again once all the food has been digested and continuing until the absorption of nourishment again commences. If this idea is correct, the appearance of the above-noted correlation would be natural.

Index of the Value of Schools.

As an approximation, assuming that the fishing efficiency of all fishermen is equal, it can be considered that the total number of fish taken N' will be proportional to the number of poles l and the duration of fishing t /this assumption does not strictly conform to the facts (table 5)/. Therefore, the catch per pole per hour $\frac{N'}{lt}$ is taken as an index of the value of a school, and is called the school value index. We can consider that the catch per pole per hour is generally proportional to the index of average density of the school $\underline{k}$ and to the index of biting qualities $\underline{q}$. Thus

$$\frac{N'}{lt} \propto kq \text{ or } \frac{N'}{lt} = akq$$ Here is a constant.

The fact that the products of k and q given in tables 2 and 3 are proportional to the values of $\frac{N'}{lt}$ calculated from observed values for N', l, and t (table 6) shows that this idea is in general correct. As the above formula will not stand if x = 0.5 in calculating the value of k, x is considered to be about 0.1.

Table 5.—Number of fish taken and duration of angling for schools accompanying sharks

Duration of angling (t)	Number of fish taken	Fish per hour	Fish per pole per hour
5 hrs.	1,111	about 223 fish	about 11 fish
2-4 hrs.	1,169	113	17
1 hr.-1 hr. 30 min.	525	112	13
30-59 min.	57	114	6
less than 30 min.	74	> 111	> 6

Table 6.—Index of value of schools

Type of School	Observed N√(1t)	Calculated 50.5 X kg.* (x = 0.1)	Calculated 51.8 X kg.* (x = 0.0)
Bird	8	10	6
Whale	57	57	57
Shark	26	30	31
Unaccompanied	43	66	67

* 50.5 and 51.8 are the numbers used to multiply in order to make the N√(1t) and values for whale-accompanying schools agree.

Summary

A study has been made of the distribution of objects with which skipjack schools are associated in the southern portion of the Northeastern Sea Area and the northeastern portion of the Inner Sea Area, and it has been found that there is a marked difference in the distribution of these objects corresponding to a sharp change in oceanographical conditions in the waters east of [illegible]. It has also been found that salinities may be taken as an indirect indicator of the boundaries of the distribution of these objects. The density and biting qualities of schools have been shown numerically by means of indices, and the characteristics of each type of school have been shown. An index of value for schools has been postulated and has been found to be roughly proportional to the products of the density and biting quality indices. Interesting facts have also been demonstrated concerning the relationship between biting qualities and stomach content and the relationship between duration of fishing and number of fish taken.

This paper is based chiefly on the detailed records of observation by the Fukushima Prefecture Fisheries Experiment Station, and I wish to express my thanks to the personnel of the Station who made these data available. Thanks are also due to Dr. [illegible] Terada and Dr. [illegible] Tanaka for various comments on the results of this study.

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